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A scene from the engineering drawing office of Humphreys & Glasgow Ltd., London.

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LE TRAITEMENT CHIMIQUE À HAUTE PRESSION: UNE REVUE

par W. Strauss

On discute l'influence des pressions extrêmement élevées sur les équilibres chimiques, les vitesses de réaction et la polymerisation, ainsi que sur les conductivités électriques des acides, sels et bases.

B.C.E., 4, No. 6, 390. U.D.C. No. 664.8.047.

L'APPAREILLAGE SUR GRANDE ÉCHELLE POUR LE SÉCHAGE FRIGORIFIQUE DES COMESTIBLES

par James C. Forrest

On résume les méthodes courantes pour la conservation des comestibles, notamment par le séchage frigorifique. Les problèmes les plus importants de l'instrumentation et de la construction des sécheurs sont discutés.

B.C.E., 4, No. 7, 395. U.D.C. No. 66.071.7.

UNE CORRÉLATION POUR LES REMPLISSAGES DES COLONNES D'ABSORPTION

par F. R. Whitt

Un système simple et de grande utilité pour les constructeurs a été développé pour la corrélation des variables et de l'hauteur d'un unité de transfert pour les remplissages annulaires. D'autres données corrélatives concernant les unités de transfert ou les plâteaux équivalents théoriques sont également indiquées.

B.C.E., 4, No. 7, 398. U.D.C. No. 66.045.2: 621.039.534.

UNE MÉTHODE POUR L'ÉTUDE DE L'ÉCOULEMENT EN TUBES À NERVURES

par A. Atherton

L'auteur décrit un traceur électrolytique pour l'étude de l'écoulement d'un liquide en tubes à nervures transversales et pour l'obtention des données fondamentales pour la construction de la géometrie des nervures.

B.C.E., 4, No. 7, 403. U.D.C. No. 66.012:658.5.

PROBLÈMES D'ORGANISATION DANS LA MISE À POINT DES PROJETS D'INSTALLATIONS CHIMIQUES

par M. Davidmann

La coopération effective d'un grand nombre d'experts est indispensable pour la mise à point des projets d'organisation. Il est erroné d'essayer à atteindre ce but par la nomination d'un coordinateur. La nécessite d'une definition nette des tâches et responsabilités différentes est soulignée.

B.C.E., 4, No. 7, 411. U.D.C. No. 66.045.1:661.666: 621.7.02:669.14.

UNE APPLICATION NOUVELLE POUR LES ÉCHANGEURS DE CHALEUR GRAPHITIQUES

par B. A. Garman, A. Hilliard et N. H. Riches

Un aperçu des économies resultantes de la substitution des échangeurs graphitiques du type polybloc pour les serpentins de plomb ou les échauffeurs à vapeur vive dans une installation pour le décapage des serpentins, des barres ou des tiges d'acier. L'installation décrite permet une réduction des coûts de combustible ainsi que d'entretien.

Kurzreferate

B.C.E., 4, No. 7, 386. U.D.C. No. 66-987.

DIE CHEMISCHE BEARBEITUNG UNTER HOCHDRUCK: EINE ÜBERSICHT

von W. Strauss

Der Einfluss von Höchstdrucken auf chemische Gleichgewichte, Reaktionsgeschwindigkeiten und Polymerisierung, sowie auf die elektrische Leitfähigkeit von Säuren, Salzen und Basen wird erläutert.

B.C.E., 4, No. 6, 390. U.D.C. No. 664.8.047.

GROSSANGELEGTE GERÄTE FÜR DIE GEFRIERTROCKNUNG VON LEBENSMITTELN

von James C. Forrest

Eine Übersicht der heutigen Methoden für die Konservierung von Lebensmitteln mit besonderer Rücksicht auf die Gefriertrocknung wird gegeben. Die Hauptprobleme der Instrumentierung und Planung von Trocknern werden besprochen.

B.C.E., 4, No. 7, 395. U.D.C. No. 66.071.7.

EIN KORRELATIONSSYSTEM FÜR FÜLLUNGEN VON ABSORPTIONSKOLONNEN

von F. R. Whitt

Eine einfache, für den Konstrukteur wertvolle Methode der Korrelation von Veränderlichen sowie von der Höhe von Übergangseinheiten für Ringfüllungen wurde entwickelt. Auf andere Korrelationsdaten im Zusammenhang mit Übergangseinheiten oder äquivalenten theoretischen Tellern wird gleichfalls hingewiesen.

B.C.E., 4, No. 7, 398. U.D.C. No. 66.045.2: 621.039.534.

EINE METHODE FÜR DIE UNTERSUCHUNG DER STRÖMUNG IN GERIPPTEN RÖHREN

von A. Atherton

Ein elektrolytischer Indikator für die Untersuchung der Strömung einer Flüssigkeit in quergerippten Röhren und für die Erhaltung der wichtigsten Unterlagen für die Planung der Rippengeometrie wird beschrieben.

B.C.E., 4, No. 7, 403. U.D.C. No. 66.012:658.5.

ORGANISATIONSPROBLEME IN DER PLANUNG VON CHEMIKALIENFABRIKEN

von M. Davidmann

Wirksame Zusammenarbeit vieler Spezialisten ist für die Planung der Betriebsorganisation unentbehrlich. Der Versuch, dieses Ziel durch die Ernennung eines Koordinators zu erreichen, wird als fehlerhaft erkannt. Die Erforderlichkeit einer klaren Festlegung verschiedener Aufgaben und Verantwortlichkeiten wird betont.

B.C.E., 4, No. 7, 411. U.D.C. No. 66.045.1:661.666: 621.7.02:669.14.

EINE NEUARTIGE ANWENDUNG FÜR GRAPHITISCHE WÄRMEAUSTAUSCHER

von B. A. Garman, A. Hilliard und N. H. Riches

Die mittels der Ersetzung von Bleischlangen oder Frischdampfheizern durch graphitische Wärmeaustauscher der Polybloc-Art erzielten Ersparnisse in einer Anlage für das Abbeizen von Stahlschlangen, -stangen und -stäben werden besprochen. Die beschriebene Anlage führt zu einer Verminderung sowohl der Wartungs- als auch der Brenstoffkosten.

Резюме

B.C.E., 4, No. 7, 386. U.D.C. No. 66-987.

ХИМИЧЕСКАЯ ОБРАБОТКА ПОД ВЫСОКИМ ДАВЛЕНИЕМ: ОБЗОР

У. Страусс.

Обсуждается влияние высочайших давлений на химические равновесия, скорости реакции и полимеризацию, а также на электрическую проводимость кислот, солей и оснований.

B.C.E., 4, No. 6, 390. U.D.C. No. 664.8.047.

КРУПНОМАСШТАБНЫЕ ПРИСПОСОБЛЕНИЯ ДЛЯ СУШКИ ПИЩЕВЫХ ПРОДУКТОВ ПРИ ТЕМПЕРАТУРЕ НИЖЕ 0° С

Джейме Ч. Форрест.

В статье дается обзор методов, употребляемых в настоящее время для консервирования пищевых продуктов. Особенно упомянуты процессы сушки при температуре ниже 0° С. Обсуждаются основные вопросы инструментации и конструкции сушилок.

B.C.E., 4, No. 7, 395. U.D.C. No. 66.071.7

СПОСОБ КОРРЕЛЯЦИИ ДЛЯ НАСАДОК ПОГЛОТИТЕЛЬНЫХ КОЛОНН

Ф. Р. Уитт.

Разработан простой и ценный для конструкторов способ корреляции переменных, а также переходного узла для кольцевых насадок. В статье даются ссылки на другие данные о переходных узлах или эквивалентных теоретических тарелках.

B.C.E., 4, No. 7, 398. U.D.C. No. 66.045.2: 621.039.534.

СПОСОБ ИССЛЕДОВАНИЯ ТЕЧЕНИЯ ПО РЕБРИСТЫМ ТРУБАМ

Э. Этертон.

Описывается электролитический индикатор для исследования течения жидкости по поперечно-ребристым трубам, а также для получения основных данных относительно конструкции ребер и их геометрии.

B.C.E., 4, No. 7, 403. U.D.C. No. 66.012:658.5

ОРГАНИЗАЦИОННЫЕ ЗАДАЧИ В СВЯЗИ С ПРОЭКТИРОВАНИЕМ ХИМИЧЕСКИХ УСТАНОВОК

М. Дэвидманн

Эффективное сотрудничество большого числа специалистов необходимо для проектирования организационных мер. Подход, пытающийся обеспечить такое сотрудничество назначением координатора, является неправильным. Подчеркивается необходимость в четком ограничении отдельных задач и ответственностей.

B.C.E., 4, No. 7, 411. U.D.C. No. 66.045.1:661.666 621.7.02:669.14.

НОВОЕ ПРИМЕНЕНИЕ ДЛЯ ГРАФИТНЫХ ТЕПЛООБМЕННИКОВ

Б. А. Гарман, А. Хиллард и Н. Х. Ричес.

Описываются экономии, достигнутые за счет замены свинцовых змеевиков или остро-паровых обогревателей графитными теплообменниками «поливлокового» типа в установке для травления стальных змеевиков, брусов или прутков. Описанная установка позволяет понизить затраты как на ремонт, так и на топливо.

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Mankind in Closed-loop Systems

SUPPLEMENTING in their own way the work of poets, authors and artists in the proper study of mankind, D. T. McRuer and E. S. Krendel have considered* the role of human elements in certain closed-loop systems. The control engineer achieves a logical connection between a system and its components by expressing component characteristics in terms of abstract models such as transfer functions or computer setups and then combining these models to obtain a description of system behaviour. The use of such techniques in the design of automatic control systems has met with outstanding success. But in this process, point out the authors, designers have tended to overlook one of the most versatile and in many respects most readily available and reliable components of all—the human controller. There are fairly broad areas where a suitable manual control system represents either the optimum solution or merits detailed consideration as a good possible choice. Before control engineering concepts can be applied to such cases, however, one must have a catalogue of human static and dynamic characteristics, preferably expressed in terms readily understood by the control engineer. One of the principal purposes of the paper is to provide the reader with a synthesis, in control engineering terminology, of the available data on the dynamic characteristics of human operators in certain continuous control tasks. This involves a quantitative description of human dynamics. Accordingly, the human behaviour description is expressed in terms which are compatible with conventional descriptions of control system components by the use of a quasi-linear mathematical model for the human operator. The model is composed of two components—a describing function and remnant. McRuer and Krendel examine these functions and show how to make proper engineering use of the most versatile component, optimising the complete control system for both performance and reliability.

* *J. Franklin Institute*, 1959, Vol. 267, No. 5. p. 381.

Engineering the Recovery of Urban Refuse

FURTHER—and valid—propaganda for mechanised municipal composting has just been issued by a joint working party on the subject. To local authorities the process offers a sanitary and economical method for disposing of the by-products of urban life; to growers it offers a supply of humus, or humus-forming material, and to engineers an important field of development. Lord Douglas of Barloch states in his foreword to the report* that although the basic biological principles are well established, there is much to learn about their application to the large scale composting of urban wastes. This study will therefore be a continuing and developing one. In practice the composting of municipal refuse and sewage sludge is mainly an engineering matter, for it is essentially directed to handling as economically as possible the basic materials in such a fashion as to maintain the fundamental conditions required by the living organisms which effect the decomposition. This involves removing deleterious matter, aerating the mixture of sludge and refuse, while maintaining satisfactory moisture content and temperature. The shredded refuse and sludge must be controlled and proportioned. A tall plant operated in Jersey, which uses gravity for turning, aerating and conveying, has an output of compost of about 12,000 tons per annum. Another—based on the Dano process—consists of feeding suitable refuse into a long revolving drum called a bio-stabiliser, into which regulated quantities of liquid and air are also injected. After about a week, the composted refuse is discharged on to a screen which separates, by size, the compost from "contraries." At present, Edinburgh have installed this type of plant and their total estimated annual output of compost, with all plants in production, is 7000 tons. We learn from the Ministry of Housing that there are three further Dano-type plants in operation. These are at Leatherhead (Surrey), Redditch (Worcs.) and Radcliffe (Lancs.). Elsewhere in the country disposal is by controlled tipping or incineration. The Ministry has not yet made any comments on the report.

* Interim Report of Joint Working Party on Municipal Composting 1959. Copies from Hon. Secretary, A. G. Davies, Council Office, Woking, Surrey. 1s. 6d. (Postage 2d.)

Thinking about Water

OVER a year ago we referred to the Water Research Association as "a lively youngster." It is growing fast. In the first three years income has increased from £11,000 to over £20,000 per year; now they are hoping to raise this to £45,000 derived from the industry to qualify for a government grant of £27,000 per year. On this basis it is planning to extend the research programme by adding filtration studies, investigations on disposal and reclamation of sludge, work on analytical methods and on hydrology. Space will be available for translating on to the pilot plant scale earlier laboratory bench work on flocculation. This forms part of the pattern of increasing interest in water supplies and economies, manifest in such ways as the choice of subject for the last Jubilee Memorial Lecture of the Society of Chemical Industry and the publication of a recent special report on air-cooled heat exchangers. In the former (*Chemistry & Industry*, May 9, 1959, p. 578) E. L. Streatfield advocated the "conveyor" concept for water in industry. This means recognising that there are comparatively few cases where water takes part in a chemical reaction and is consumed. More often it conveys solids or heat. Why then should one throw away the water conveyor, asked Mr. Streatfield, rather than studying methods of re-use?

The special report on exchangers appeared in *Petroleum Refiner*, April, 1959. Opening with a paper on cost comparisons for typical cooling duties, it goes on to discuss features of design and methods of carrying out field tests. One contributor is quite emphatic on the outcome of cost comparisons based on installations at a new refinery. Mr. John W. Thomas entitles his paper "Air wins even with water plentiful."

Tell C.O.I. Tell the World

ABOUT one third of the news output of the Central Office of Information is devoted to industrial, commercial, scientific and technological information. At the Annual Luncheon of the Scientific Instrument Manufacturers' Association, Mr. T. Fife Clark, C.B.E., Director-General of the C.O.I., asked for the co-operation of firms in supplying material of high quality. The office sends stories to 90 countries with a population of two thousand million people. Publications are in 30 languages, film sound tracks in 15 or more. British industrial films, private enterprise and official, are shown on T.V. in 40 countries and an official T.V. Newsreel in 21. *Verb sap.*

Displacement Flow in Porous Masses

WHAT is there in common between developing a theory for the dewatering and washing of industrial filter cakes, and assessing the future of oil production? The common feature—study of multiphase flow through porous masses—formed the subject of a two-day discussion under the chairmanship of PROF. P. V. DANCKWERTS at the Chemical Engineering Department of Imperial College, with particular reference to displacement of one fluid by another or to fluid mixing. In the oil-production industry it is thought that the long term economy may depend in large measure on efficient recovery of oil from underground formations. MR. C. VAN DER POEL of the Royal Dutch Shell Co. discussed the instability of the liquid—liquid interface for immiscible fluids in porous media and its significance in oil recovery by adding considerations of surface tension effects and scale. He showed an excellent film of water and gas drive recovery in a two-dimensional flow model of glass beads.

A paper of considerable interest but outside the direct scope of the subject was presented by DR. C. VAN HEERDEN, of the Central Laboratory of the Dutch State Mines. This dealt with surface diffusion for the flow of condensible vapours and showed that the Knudsen diffusion coefficient is applicable over a much wider range than hitherto accepted. It proved possible to work out numerical corrections over a range of ratios of mean free path of molecule to radius of capillary.

Handling Abrasive Slurries in Sulphuric Acid

DETAILS, including drawings, are given in a recent article* of the method used for discharging to atmospheric pressure a slurry at about 550 psi produced during leaching nickel and cobalt ores at Moa Bay, Cuba. The thickened slurry is preheated with recovered low-pressure steam to 160° to 180°F and pumped into reactors where high-pressure steam is injected for final heating. Ninety-eight per cent sulphuric acid is added as reagent. After leaching the slurry is flashed to atmospheric pressure. Early in the work it was decided that conventional valving had no chance of success. A complete list of possible valve trim was explored and showed that the only possible materials were fused alumina ceramics and Carborundum's Refrax. Nothing will withstand the abrasion of these slurries at high velocities for an appreciable time because their action is similar to grinding with jeweller's rouge suspended in acid. This meant that there was no real chance of throttling the flow to an exact rate, so development was aimed at finding a system wherein the valves could be operated off-on. In this way, the wear on the trim is confined to the instants of opening and closing, and the life of the trim becomes a function of the number of cycles of operation. It was decided that control should be built around standard oil field chokes.

The scheme is to provide two chokes in parallel; one, sized to handle about 90% of normal total flow, forms the terminus of the discharge pipe from the slurry cooler-boilers; the other sized to handle about 15% of normal total flow, is mounted below an off-on control valve, actuated by surge level. The controlled flow by-pass line branches off the main line 15 in. above the pad flanges on the flash tanks. The main line is flanged upstream of the by-pass. This makes a compact assembly which can be removed easily by breaking out three flanges—the two pads and the main line—after which another unit is installed. The old unit may be removed for inspection and replacement of chokes. The choke section consists of two 6-in. choke sections cemented in a section of pipe. A necessary part of the assembly is a ceramic disc with a bore somewhat larger than the choke bore to prevent erosion of the support plate due to entry turbulence.

* *Corrosion*, Vol.15 No. 4, 1959, p. 95.

Problems in Atmospheric Pollution

IT is useful to be reminded that the treatment of the effluents emanating from a process require proper attention at the design stage; and it is equally useful to have underlined some of the more pressing problems in this difficult field. There are of course plants in operation whose standards in this respect fail to meet the demands of recent legislation; there is, for example, still believed to be working in the iron and steel industry, a blast furnace which was first erected in 1711. While its longevity is no doubt a tribute to its builders and designers, they could not have made allowance for present-day limitations on pollution. The present owners of this equipment and the iron and steel industry generally, through the provision of the Alkali and Works Order, 1958, now come under the surveillance of the Alkali Inspectorate which has the task of seeing that the industry reduces its discharge of pollutants to the atmosphere. The magnitude of the task is made clear in the annual report of the Chief Inspectors of Alkali &c Works.* One problem is the dusty emission resulting from the handling of ores, and in sintering, to reduce which the inspectorate require without exception the installation of dedusting equipment.

In the case of blast furnaces the problem varies in magnitude according to whether the plants are integrated or not. In the non-integrated plant where all the gas cannot be used, the discharge of dirty gas is now prohibited and the inspectors have the job of offering practical solutions for plants where the dust burden cannot be reduced immediately to the figure of 0.01 grain per cu. ft. As regards steel production the Bessemer converters present an almost intractable problem and at present no clear line of attack for containing their emissions can be seen. For the tropænas converter, however, a solution is in sight, but for the open hearth furnaces, before much can be done, the actual discharges need assessing. Meanwhile high chimneys are a temporary measure. And then there is the copious, highly coloured and very fine fume which arises where oxygen is used, which in view of the economic necessity for this technique, is likely to become a major emission problem before very long.

Many other difficulties of a practical nature and some of the attempts made to solve them are dealt with in detail in

this report. Interesting developments in the removal of acid mists from waste gases receive mention; in one example, from an anhydrite works, electro-precipitators achieved almost quantitative removal of the mist. At another anhydrite plant ceramic filters proved to be satisfactory under some operating conditions but not under others; the character of the coke used was found to influence their performance. At some works experiments are being carried out with fibre filters and with modified Calder Fox scrubbers; and at other plants electro-precipitators are giving satisfactory results.

* "95 Annual Report on Alkali &c Works," by the Chief Inspectors, H.M.S.O., London, 1958.

Theory for Impact Milling

THE field of particle size reduction which used to be one of the most neglected areas of chemical engineering continues to attract attention. One of the latest treatments of the subject refers to impact comminution, as carried out in fixed or swing hammer milling. According to PROFESSOR DR.-ING. H. RUMPF*, the energy yield in impact comminution will be comparatively favourable if the capacity and ability of the material to absorb the energy of change-of-shape without breakage is reduced with short-term impact stressing. The better selective crushing may be associated with the fact that the stress distribution is changed compared with that for similar stressing between two surfaces.

He discusses the possibilities of energy utilisation on the basis of the laws of mechanical and elastic impact. In a comminution plant there is a wide distribution of impact possibilities. The probability of mutual particle impact can, to a first approximation, be estimated with the aid of the free-path length calculated from the MAXWELL velocity distribution. The relationship between the maximum impact stress and the essential factors influencing the operation are derived by dimensional analysis for geometrically similar and arbitrary particles having a spherical impact point. In the latter case the HERTZ equations apply.

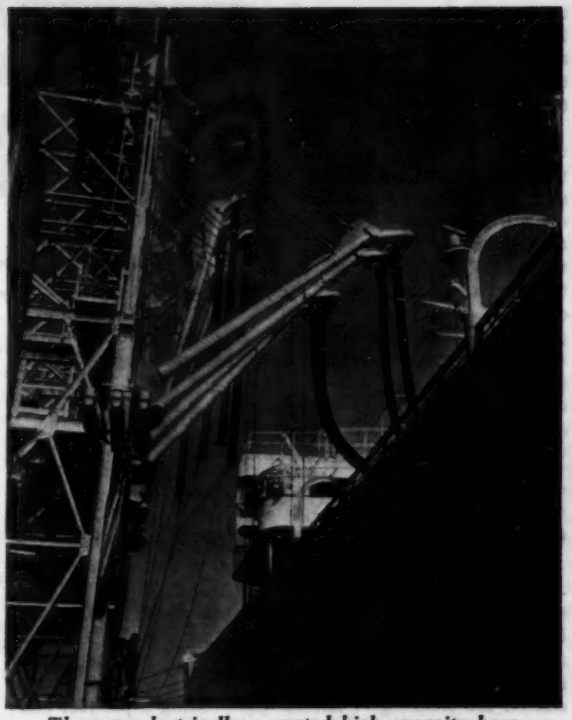
In the adjustment of impact comminution plant, a correct match between the impact velocity and the particle strength must first be found. In addition to the relationship between the strength and particle size, PROFESSOR RUMPF takes into account the influence of air friction and the limitation of the motion path in the case of small, free-path lengths. Finally he derives a simple relationship for the frequency of impact and grinding element velocity which represents the whole sphere of impact grinding.

* Professor Dr.-Ing H. Rumpf, *Chemie-Ingenieur-Technik*, May 1959, p. 323.

Oil Storage at Thames Haven

THE oil distribution and storage depot at Thames Haven, Essex, is said to be the largest and most flexible in Europe—possibly in the world. As a result of a large development programme inaugurated in 1948, the developed area now covers more than 400 acres, the tankage capacity amounts to 1,750,000 tons and the site has seven deep-water jetties and six smaller berths. Imports handled through this depot last year totalled almost six million tons. In 1948 the owners, London & Thames Haven Oil Wharves Ltd., entered into an agreement with the Shell Refining Company for the storage of both crude oil and finished products from the adjoining Shell Haven refinery. Last year refined products delivered out totalled 4,200,000 tons. Most of the tanks on the site are of the conical-top fixed roof type but a number of the later constructions have floating roofs.

During a recent visit, we were shown this large installation including the latest pump house with a sub-surface pump room to ensure "flooded suction" to the two-stage



The new electrically operated high capacity hose handling equipment at No. 10 Jetty, Thames Haven, Essex

electrically driven centrifugal pumps each capable of delivering viscous oil at more than 500 tons per hour while absorbing 250 bhp. The associated manifolds have been designed to ensure complete segregation of all products handled through the pump house while giving flexibility in routing the products handled. Valves are manually operated.

To provide faster pumping rates and quicker turn-rounds of tankers maximum pipe line diameters have been increased to up to 24 in. As a result, pumping rates have more than doubled in the last ten years. Aluminium-sheathed lines are steam traced and lagged to maintain the delivery temperatures of the heavier grades of oil which are heated to increase pumping speeds.

An interesting aside from the main function of the installation is the presence of six disused full-size batch stills, claimed to be the oldest in England.

Backmixing in Liquid-Liquid Extraction

It has long been known that the efficiency of an extraction column is reduced by the occurrence in either phase of backmixing. Ideally, each phase should flow without axial mixing, i.e. in plug flow, but in practice there is always some axial mixing and in extraction columns capable of producing high rates of mass transfer axial mixing is always pronounced. Unless this effect is taken into account in assessing the performance of a pilot-scale extractor, misleading correlations are likely to be obtained which in turn will give rise to errors when the results are extrapolated to large packings or column diameters.

From C. A. SLEICHER of the Shell Development Co., California, comes a useful approach to this problem.* He assumes that the extraction process can be represented by a diffusional model and points out that axial mixing in the

continuous phase in an extraction column is the result of both turbulent and molecular diffusion in the axial direction, as well as non-uniform velocity and subsequent radial mixing. Both these effects cause a decrease in the net driving force for mass transfer.

By means of a study aided by digital computation he derives a number of charts which show the effects of backmixing. These include one which relates the efficiency of extraction to the number of transfer units, with ranges of feed and solvent-phase Peclet numbers (based on column length) as parameters. This shows that in no region of parameter space does the effect of backmixing reduce the extent of extraction by more than 50% and even for low Peclet numbers the efficiency is reduced by less than 25%. Another graph is given to show how the height of an extraction column must be increased or the feed/solvent ratio decreased to bring about a given change in extraction. Finally the author presents a correlating equation for the determination of column efficiency defined as the ratio of the height of a plug-flow column to the height of a column actually required.

* Sleicher Jr, C. A. "Axial Mixing and Extraction Efficiency." Paper presented to the A.I.Ch.E. Atlantic City Meeting, March 1959

Cracking Natural Gas in the U.S.S.R.

ACETYLENE is such a pregnant raw material that there is special interest in a review by a high Soviet official* of their plans for increasing production up to 500,000 tons between now and 1965. The major part of the acetylene produced industrially in the U.S.S.R. is at present derived from calcium carbide. However they are now turning to electric arc cracking of natural gas yielding a product containing 14% of acetylene and 57% of hydrogen. The gases are purified and acetylene separated by extraction with dimethylformamide, acetone or butyrolactone. One ton of acetylene is produced from 4600 cubic metres of natural gas and 3.2 tons of synthetic ammonia from 5650 cubic metres of by-product gases in addition to the carbon black. They are also working on oxidative pyrolysis of methane; part is oxidised to carbon monoxide and free hydrogen, while the remainder is converted into acetylene. The gases formed contain 8.5% acetylene and 55% hydrogen. Here, one ton of acetylene is produced from 6300 cubic metres of natural gas and 3500 cubic metres of oxygen are used. In the near future the Lisichansk Chemical Combine of the Voroshilovgrad Sovnarkhoz is due to complete the construction of a large experimental industrial installation based on this process.

High-temperature pyrolysis at 1100° C will also be applied using propane, butane and heavier hydrocarbons, yielding about 13% acetylene. Preliminary data indicate that 5.2 tons of propane or butane and 20-25 tons of steam are required per ton of acetylene. In addition 3000 cubic metres of methane-hydrogen fraction are produced, which can be converted to 1.6 tons of synthetic ammonia, and also 950 cubic metres of ethylene can be isolated. It is proposed to apply the new process in the Bashkir Economic Region, which has extensive supplies of hydrocarbon gases.

* Antonov, V. Chief of Administration, State Committee on Chemistry at the Council of Ministers USSR; *Promyshlenno-Ekonomicheskaya Gazeta*, 1959, Vol 4, No. 22 (477), p. 2.

Can you look into your plant with radar?

HOPING to add to the range of instruments available for examining what happens inside the opaque walls of plant, workers of the British Iron and Steel Research Association have been considering the idea of using radar. In co-operation with the Electrical Department of the Imperial College of Science and Technology, they have carried out laboratory tests to examine whether a radar method can be used to delineate the stockline contour of an operating blast furnace. Work is evidently at a very preliminary stage. There would presumably be two main problems: is it possible to use radar for this purpose over short distances and, if so, will the equipment stand up to the severe conditions in and around the blast furnace? In laboratory tests the position of the surface can now be measured accurately by this means and atmospheres densely laden with dust do not interfere with the measurement. It is hoped that an attempt can soon be made to measure the stockline depth of an operating furnace through a stock-rod hole.

It may be recalled that earlier trials using ultrasonics had failed due to the effect of gas temperatures on the velocity of the sound waves which interfered with the accuracy of measurement. Meanwhile at Leatherhead gamma radiation is being used to control the level of a bed of fuel in the gasifier operated by C.J.B. Ltd. This does not give the profile of the bed but generally indicates the position of the surface. Clearly, the present B.I.S.R.A. trials have given promising results which go beyond the scope of the gamma-ray technique. If they are confirmed on operating furnaces the method may have considerable importance for other cases of maintaining control over the height and contour of a bed of granular solids, particularly if it could be developed also to determine voids in the bed.

Isotopes: Ideas Suggested

CAN a catalogue suggest ways of solving problems? After looking through "Isotopes at Work" we think it is very likely. This is a classified index* of industrial uses of radio-isotopes prepared by the Atomic Energy Research Establishment at the special request of the Institute of Directors, and is said to be the first of its kind in the world. The list is intended to illustrate the ways in which isotopes are employed or are likely to be employed with advantage in industrial research and process control; it includes a brief list of techniques. It is known that applications have included studies of mixing efficiency, measurement of separation process efficiency and "carry-over" in distillation as well as direct operational uses for static elimination or in level gauges. In checking material balance, losses of valuable materials such as gold and mercury have been traced by radio-isotopes. There are likely to be many cases where it would be of advantage to follow up the invitation to send enquiries to the A.E.R.E. Isotope Division at Harwell.

* Institute of Directors, 1959, 2s.

Testing a Low Loss Bend

IT seems remarkable that there has not been more attention paid to a low loss design for a pipe bend which has been known for many years and was discussed in a paper in *Journal of Aeronautical Science* in 1946 (Volume 13, No. 11, page 587). At the British Hydromechanics Research Association, a well instrumented bend of this type has been set up and investigation has just started using a uniform flat front upstream velocity distribution. It is intended later to work with various other types of distributions, to examine the effect of boundary layer thickness of the approach flow on head losses in the bend.

Design is based on applying potential flow theory to give nearly constant pressure along the inside wall. This reduces the tendency towards separation; it therefore decreases the energy losses which in a bend occur mainly in the eddies set up in the regions of separated flow. It is reported that only 0.3 to 0.5 of the normal dynamic head loss of a conventional bend occurs in this design. The lower figure corresponds to minimum eddy formation and is attained when the bend is "tailor-made" for constant flow and pressure of one fluid. There is some reduction in the gain where variable conditions are encountered.

British Chemical Engineering
A HEYWOOD PUBLICATION

Coal Chemicals

WHAT is the significance of coal processing to the coal industry and the chemical industry? For many years there has been talk of the need to cease the waste of coal involved in using it as a fuel; emphasis, we are advised, should rather be placed on realising the chemical content of coal. The present crisis in the coal industry is naturally reviving interest in this concept and it is therefore of some value to examine the prospects.

There are, of course, already fields in which coal derivatives are being used for their chemical content. The chemical used in the largest tonnage in Britain—roughly 12 million tons last year—is metallurgical coke which serves both for heating and reduction of metal oxides. It was interesting to note the pæan of praise for carbon by Sir Charles Goodeve, F.R.S., in the last Coal Science Lecture. Sir Charles thought that the few limitations in the use of carbon in metallurgical reactions arose because chemical engineering had not yet taken full advantage of the basic kinetics and thermodynamics of these reactions; they should be able to proceed at enormous speeds but, in practice, we did not mix reactants fast enough.

In addition, a range of by-product chemicals is produced during carbonisation and enters into trade in the normal way in competition with their counterparts from other sources. This includes benzene, toluene, xylenes, naphthalene, ammonia and phenols. Coal is in fact one of the main sources for several of these products. Expansion in demand for metallurgical coke will inevitably result in increases in the future quantities of the by-products. This source will thus be producing more of these important organic intermediates mainly from conventional carbonising processes—later possibly from newer variants of them —apart from any thought of using coal for synthesis.

What is sometimes implied in these discussions of "valorising" the coal for its chemical content is that production of chemicals may have a major bearing on the future of the coal industry, enabling us to turn largely to oil or nuclear fuels for our energy supplies. Setting aside the problems of expanding the latter two sources, the simplest consideration of some important relative quantities shows how unjustified this is unless entirely different types of chemical utilisation are envisaged, such as production of material used extensively in food, building or clothes. Coal output is around 200 million tons per year, while it is unlikely that all chemical production, apart from the special case of metallurgical coke, add up to anything approaching 10 million tons. Thus the conversion of coal on any appreciable scale into chemicals as normally defined could not be absorbed by present or conceivable markets.

If we turn to gasification we find further considerations involved. Pressure gasification compares favourably with present-day gas-making from coal. It shifts the demand from the best caking coals to poorly caking coals which are generally easier to mine and it produces no coke. It therefore gives flexibility to the gas and coal industries and helps in terms of national reserves; it is not likely to sell more coal, although it might be thought to help the coal industry to avoid getting squeezed out of gas-making.

Similarly, the production of smokeless fuels—a field which the Coal Board is now entering with the setting-up of a new Process Development Department—will have other consequences than that of opening up a new market. It is likely to make the air cleaner and be of great social benefit; as a side-line, it will yield new types of tar which will then become a source of chemical products, but again is not likely to increase demand for coal, though it may stem an expected future decline in demand for house-coal. This decline has not yet started. Surprisingly this was one of the few main fields of consumption where demand remained fairly stable during the last few years.

All this appears to add up to the conclusion that the only form of coal processing likely to show prospects for expanding useful coal consumption is in the use for synthesising oil. This is an expanding market capable of absorbing tens of millions of tons. The Ministry of Power has set up a committee to review the work that has been done in recent years on the development of processes in which coal is the basic raw material. It has the limited terms of reference of considering processes "which will produce marketable products of a chemical or a gaseous or liquid hydrocarbon type". In addition, it is charged with making recommendations about further research and development, including considering the type of organisation best suited to carry out such work. These terms of reference appear to exclude smokeless fuel products which are being produced mainly in order to complete the intentions of the Clean Air Act. This review has not come too soon. Research in these fields is being carried out by a number of agencies—formerly at the Fuel Research Station at Greenwich and now at the new Warren Springs laboratory, but also in colleges, at the B.C.U.R.A. and under the auspices of the Gas Council. Oil from coal involves a complex of fiscal, political and social issues, as well as the more obvious kinds of economic assessment. Probably the commercial possibilities depend largely on Government attitudes towards the size of oil imports. However, even in normal economic terms certain trends are noteworthy.

It is widely held that the price of oil is likely to rise, and there has been the welcome turn within the coal industry of seeing the cost of production fall. These are trends which give rises to fresh hopes for oil-from-coal processes. There is some evidence that there may have been exaggerated estimates of the extent to which coal has lost markets due to oil competition. A large part of the fall in demand of the last couple of years has been due solely to the general recession. Nevertheless, there have been losses to oil, which is often found a more convenient fuel to handle and use. It will be interesting to see if our indigenous coal can rise again and re-win its fuel markets by transforming itself into a refined liquid form.

64—987

HIGH PRESSURE CHEMISTRY — A SURVEY

How high pressures affect gas- and liquid-phase reactions

by W. STRAUSS, M.E., M.Sc., Ph.D.

ALTHOUGH the process industries—chemicals, plastics, paper—have always used heated autoclaves for batch processing, continuous high-pressure processing is of recent origin. In 1920 the only continuous industrial high-pressure plant was used in the synthesis of ammonia. This was introduced in Germany between 1910 and 1913 when the Badische Anilin und Soda Fabrik (B.A.S.F.) set up the first Haber-Bosch ammonia synthesis plant at Oppau. Within 12 years a high-pressure methanol synthesis plant had been added, the first of a number of subsidiary processes which are today frequently found in association with ammonia synthesis. The pressures used in these processes were in the range of 200 to 300 atm.* with temperatures of 500° to 600°C for ammonia synthesis and 390° to 425°C for methanol synthesis. The CLAUDE ammonia process, which was introduced about 1930, raised operating pressures to about 1000 atm. Two further processes which became of commercial importance in the 1930s were the manufacture of motor spirit by pressure hydrogenation of coal and the synthesis of urea by the high-pressure interaction of ammonia with carbon dioxide. The pressure polymerisation of ethylene, first discovered by I.C.I. in 1933, and requiring pressures of 1000 to 2000 atm. at temperatures of about 200°C, has been carried out on a large scale since the beginning of the 1939-45 war.

Since then new metals and alloys of great strength and corrosion resistance have become available, making possible the manufacture of chemical process plant able to operate under extreme conditions of temperature and pressure. Industrial processes employing pressures of thousands of atmospheres can now be undertaken.

General Considerations in High-pressure Research

Industrial high-pressure plant design has been dealt with extensively by a number of authors,[1–4] while the special techniques and small-scale equipment required for high-pressure research are described by BRIDGMAN[5] and HAMANN.[6] A comprehensive review has just been written by BETT and NEWETT.[7] Two American Chemical Institute symposia published in *Ind. Eng. Chem.*[8, 9] deal generally with problems of pilot-scale equipment and safety in high-pressure research laboratories. American safety practice is of the same order as for explosives research, particularly when handling compressed gases.

Each new range of pressures tackled by the experimenter confronts him with new techniques and experimental difficulties. At ordinary temperatures the limitations of the various techniques are approximately as follows:

to 150 atm.: pressure vessels can be designed using "thin cylinder" formulæ. Commercial valves and fittings associated with high-pressure boiler practice can be employed;

to 3000 atm.: pressure vessels can be designed according to the "thick cylinder" formulæ (LAMÉ's relations). Monobloc construction is adequate, but tends to become very cumbersome for larger vessels. This can be overcome by the techniques of autofrettage, of wire-winding or of multiple shrunk cylinders;

to 6000 atm.: this is the upper limit to which equipment is available commercially. This includes pressure vessels, pumps, intensifiers, connections and fittings, and Bourdon-tube type pressure gauges;

at 7500 atm.: and at 0°C mercury solidifies. Mercury is frequently used as an inert sealing liquid for glass reaction vessels, isolating the reaction phase from the pressurising fluid. Reaction vessels of Fluon using moving Fluon plugs for isolation have proved satisfactory to 45,000 atm.;

at 11,300 atm.: and at 25°C water solidifies to ice VI;

at 15,000 atm.: and at 45°C water solidifies to ice VI. This is the upper limit to which a monobloc steel cylinder (outer to inner diameter about 10 to 1) can be repeatedly used;

20,000 atm.: represents the limit at which steel pistons can be used. Pistons of sintered tungsten carbide (carboloy) must be used at this and higher pressures. Multiple cylinders (see Fig. 1) can be used which give, with increases in pressure, increased support to the inner vessel when the latter is pushed into the cone-shaped outer one;

at 50,000 atm.: methanol solidifies (25°C). Methanol should freeze at 30,000 atm., but can often be compressed to 50,000 atm. without the solid phase appearing—and it can be kept indefinitely in this metastable condition. This is the upper limit to the study of liquid phase phenomena at ordinary temperatures, as all other liquids solidify at lower pressures; and

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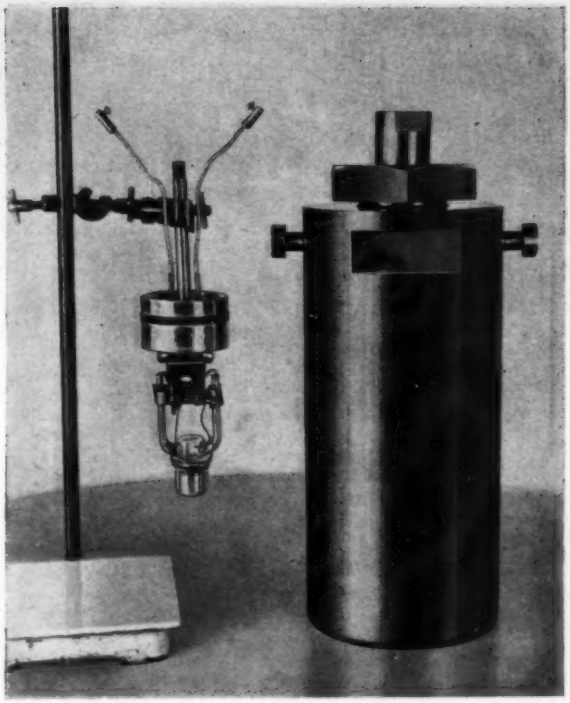
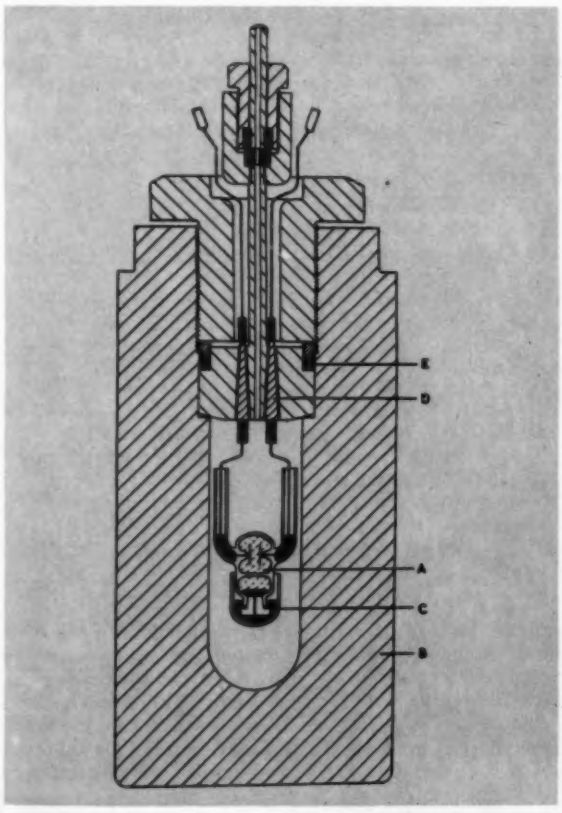
* The unit of pressure used in these articles is the standard atmosphere: 1 atm. = 760 mm mercury = 14.72 lb./sq. in. = 1.013 bar = 1.033 kg/sq. cm.

† Accepted for publication 26 February, 1958.



Figs. 1 (above) by courtesy of the C.S.I.R.O., Australia, and 2, Pressure vessel and conductance cell used for measuring conductances to 3000 atm. The glass conductance cell, A, capacity 8 ml., is mounted in a high-tensile steel pressure vessel, B. Mercury in the cap, C, isolates the solution being tested from the pressurising fluid. Electrical connections with the cell are established through glass insulated steel cones, D. The vessel is closed by a Bridgman "unsupported area" packing, E, of rubber.



at 85,000 atm.: and above, together with temperatures in excess of 2500°C, diamonds can be made.

Higher pressures can be obtained by the use of shock waves. Under these conditions some non-metallic compounds show metallic properties.

These approximate limits apply only in the lower ranges of temperature, to about 500°C. Most steels exhibit creep properties above this temperature which complicate equipment designs. When working at high temperatures the furnaces are often built inside the pressure vessel.

All the commercial high-pressure processes at present in operation involve gases as their starting materials, and depend largely on the fact that with the pressures used large changes in concentration and volume are produced. When pressures of the order of thousands of atmospheres are considered, other factors than the changes in volume and concentration become of importance. Under these conditions, compounds which are normally gases have the same density as liquids, and have compressibilities of the same order as liquids or solids. The volumes of the individual molecules account for a large part of the total volume of the material. In dilute solutions the changes in the properties of the solvent, its viscosity and dielectric constant play an important part in the pressure effects observed in the properties of the solute.

The range of pressures usually tackled in an industrial research laboratory is up to about 5000 atm., although exploratory work by I.C.I. and Du Pont (Wilmington) has been at double this pressure. The accuracy of experimentation also decreases with increases in pressure, and the quantitative discussion which follows is based on experimental work with a maximum pressure of 12,000 atm. for equilibria and 15,000 atm. for most types of reactions, although 45,000 atm. is the highest pressure at which the rate of a chemical reaction has been measured.

Chemical Equilibria at High Pressure

It has been stated[6] that, in general, two main principles govern the behaviour of a system in compression: the macroscopic principle of LE CHATELIER and the principle of microscopic ordering. LE CHATELIER'S principle states that if a change occurs in one of the factors, such as temperature or pressure, under which a system is in equilibrium, then the system tends to adjust itself to annul, as far as possible, the effect of the change. A familiar example is the ammonia synthesis equilibrium:

$$N_2 + 3\,H_2 \rightleftharpoons 2\,NH_3$$

An increase in pressure shifts the equilibrium from left to right, as two molecules of ammonia occupy less volume at the same pressure than four molecules of the reactants. In a solution in a polar solvent the solvent molecules tend to pack more closely around an ion than around an unchanged molecule. Here the total volume is not determined by the total number of entities and so the ionisation of a weak acid is favoured by pressure.

At extremely high pressures (and in some cases at comparatively low ones) crystalline solids will undergo transition into more economically packed forms, being ultimately converted into metallic lattices which are still more closely packed. Generally, the effect of pressure is to increase the order in a system, which is a process accompanied by a decrease in entropy. A well-known exception to this is the melting of ordinary ice (ice I), which can occur when either the temperature or the pressure in the system is increased. Here the disordered liquid state (water) is more dense than the ordered solid state (ice I).

Equilibria in the gaseous phase: The general formula for a chemical equilibrium can be written:

$$aA + bB + \ldots + . \rightleftharpoons lL + mM + \ldots + .$$

Defining the equilibrium constant K_f in terms of the fuga-

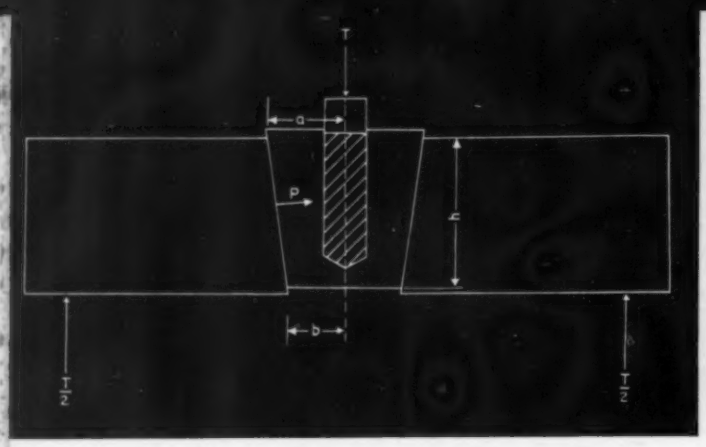


Fig. 3. Bridgman's method of providing support to vessels with very high internal pressure (Ref. 5, fig. 88).†

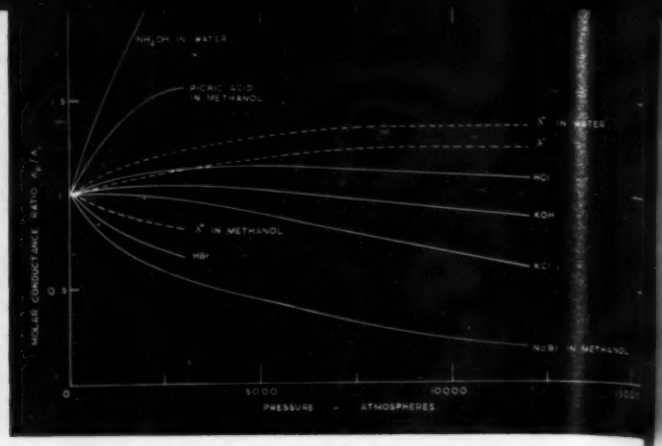


Fig. 4. Effect of pressure on conductance of electrolyte solutions plotted as ratio of molar conductance at high pressure to that at one atm.[12, 18]

cities f of the components in equilibrium, together with a reference pressure P_o (usually taken at 1 atm.)

$$K_f = \frac{(f_L/P_o)^l\,(f_M/P_o)^m}{(f_A/P_o)^a\,(f_B/P_o)^b} \ldots = \prod_L{}^{*}\,(f_L/P_o)^l / \prod_A\,(f_A/P_o)^a \qquad \ldots.(1)$$

The function which is usually measured in gas phase reactions is K_p, defined by:

$$K_p = \prod_L\,(P_L/P_o)^l / \prod_A\,P_A/P_o)^a \qquad \ldots.(2)$$

$$\text{where } P_A = x_A P$$

x_A being the mole fraction of A in the equilibrium mixture, and P being the total pressure of the mixture. Introducing activity coefficients $\gamma_A \ldots$, defined by:

$$\gamma_A = f_A/P_A, \text{ etc.} \qquad \ldots.(3)$$

Equation (2) can be rewritten:

$$K_p = K_f \prod_A\,(\gamma_L)^a / \prod_L\,(\gamma_A)^l = K_f/K_\gamma \qquad \ldots.(4)$$

$$\text{where} \qquad K_\gamma = \prod_L\,(\gamma_L)^l / \prod_A\,(\gamma_A)^a$$

The product K_γ is pressure dependent, approaching unity at low pressures, while at high pressures it may be greater or less than one. Consequently, K_p is also pressure dependent. At low pressures K_p is equal to K_f and can be measured or calculated from the standard free energies of the reactant gases. So if K_γ can be calculated as a function of the pressure, it is possible to predict K_p at high pressures. Combining Equations (2) and (4) above, the effect of pressure on the product of an equilibrium mixture can be obtained from:

$$\prod_L x_L{}^l = \prod_A x_A{}^a \frac{K_f}{K_\gamma}\left(\frac{P}{P_o}\right)^{\Sigma a - \Sigma l} \qquad \ldots.(5)$$

In the case of ammonia synthesis this gives:

$$x^2NH_3 = x_{N_2}\,x^3H_2\,\frac{K_f}{K_\gamma}\left(\frac{P}{P_o}\right)^2$$

showing that pressure favours the formation of ammonia both directly through the P^2 term and indirectly through the factor $1/K_\gamma$, which increases with pressure.[6]

Equilibria in the Liquid Phase: From thermodynamic principles it may be shown that the equilibrium constant K is related to the pressure P by the relation

$$\triangle V = (\partial \triangle G/\delta P)_T = RT\,(\partial \ln K/\delta P)_T \qquad \ldots.(6)$$

where $\triangle V$ represents the total molar volume change accompanying the reaction and $\triangle G$ the free energy change accompanying the reaction. In concentrated solutions (where no single component is present in much greater concentration than the others) an increase in pressure will shift the equilibrium in favour of the denser component. This has been shown quantitatively for the cis-trans isomerisation of 1:2 dichlorethylene[10] in agreement with Equation (6). But measurements of other concentrated solutions agree only qualitatively with it.

Although dilute solutions are rarely used in industrial processing, except in biochemical processes such as brewing, their study leads to a better understanding of the underlying phenomena governing the chemical behaviour of a system. In some cases, one of the reactants, or some of the impurities, which have a negligible effect at ordinary pressures may be far more important at high pressures.

In dilute solutions it has been found that the role of the solvent is of primary importance and the interaction of the reactant (or product) with the solvent must be considered. Thus when a molecule dissociates to give ions, a process which occurs in the ionisation of a weak acid or base, there is an overall diminution in volume due to the contraction which occurs when the polar solvent molecules freeze around the ions. The equilibrium constant—in this case the dissociation constant—is markedly increased by pressure. Typical examples are given in Table 1. The changes observed are greater in methanol than in water, the two solvents which have been most extensively investigated. On the basis of a simple electrostatic model it is possible to predict the changes in free energy[11, 12] and molar volume[13] in such a system.

The case of an ion/ion equilibrium can be treated similarly; the equilibrium

$$CoCl_4{}^{2-} + Co^{3+} \rightleftharpoons 2\,Co^{2+} + 4\,Cl^-$$

being favoured in the left-to-right direction, in the direction of the larger numbers of ions by increases in pressure.[14] The number of ions alone, however, does not determine the effect of pressure. The electrostriction round a triply-charged ion is very great, and may outweigh the effect of a single- and a double-charged ion together.[15]

When molecules are in equilibrium, as in a keto-enol tautomerism, pressure favours the enol form in a polar

† The pressure exerted by the collar is related to the total thrust, T, for small cone angles, by the equation:

p (pressure per unit area exerted by the collar)

$$= \frac{T}{\Pi(a^2-b^2)}$$

In an actual apparatus used by Bridgman, h was 1 in., a was 0.516 in., the area of the annulus was 0.160 in., with a taper of 1.25 in. per ft, and the piston diameter was 0.265 in. Here a force of 50,000 atm. on the piston will give a value of p of 17,200 atm. (neglecting friction). The material used for the collar was chrome vanadium steel, the stopper was of "solar" steel (1% Si, 0.4% Mn, 0.5% Mo, 0.5% Co), while the piston was of Carboloy No. 905, and the lubricant used was lead foil, 0.002 in. thick.

* Π indicates the products of a series of terms.

solvent, because the enol form is more solvated due to hydrogen bonding. In a non-polar solvent, or without solvent altogether, the equilibrium is virtually unchanged by pressure.[16] Free radical dissociations are not favoured by pressure, as the initial stage of the dissociation is the stretching of a bond which is an increase in the volume of the molecule, but no solvation takes place which would counteract this by an overall volume decrease.

Acids, Bases and Salts

The characteristic of dilute solutions most readily determined experimentally at high pressures is the electrical conductivity. The measurements of the conductances of a large number of dilute solutions of acids, bases and salts at high pressures present some general conclusions.

Strong Salts: In aqueous solutions the values of the molar conductances first increase slightly (to pressures of about 2000 atm.). At higher pressures they decrease. This behaviour arises from two competing effects; the compression increases the number of ions in a unit volume of solution, but simultaneously reduces the mobility of the ions by raising the viscosity of the solvent. The ions themselves are compressed at high pressures and so WALDEN's rule—that the product of the molar conductance and the viscosity is a constant—will not hold. In methanolic solutions the conductances of salts show a steady and much larger decrease over the whole measured range. This difference is due to the relatively greater increase in the viscosity of methanol at the higher pressures.

Strong Acids and Bases: It has been shown that the conductance of a strong acid or base in water essentially consists of two mechanisms: the conductance due to the H_3O^+ (or OH^-) ions, which can be shown to exist sufficiently long to move as an H_3O^+ (or OH^-) entity, and the conductance due to a proton transfer mechanism. By making the reasonable assumption that the H_3O^+ ion has the mobility approximately that of a K^+ ion, and a Cl^- ion is similar to that of an OH^- ion, the excess conductance due to the proton transfer mechanism can be estimated from

$$\Lambda^+ = \Lambda_{H^+} - \Lambda_{K^+} = \Lambda_{HCl} - \Lambda_{KCl}$$

and

$$\Lambda^- = \Lambda_{OH^-} - \Lambda_{Cl^-} = \Lambda_{KOH} - \Lambda_{KCl} \quad .$$

At atmospheric pressure the proton transfer mechanism accounts for 80% of the hydrogen ion conductance (HCl in water) and 70% of the hydroxyl ion conductance (KOH in water). In aqueous solution the excess proton conductance increases with pressure to a maximum at about 10,000 atm. It has been suggested that the pressure assists the proton transfer mechanism, as it provides some of the repulsion energy needed to bring the oxygen atoms close enough for proton transfer to occur. The maximum can be accounted for by the hindered rotation of the water molecules at the very high pressures, as the rotation of the molecules into a position favourable for proton transfer is the rate-determining step in the mechanism. This means, in practice, that increasing pressures increase the mobility of the protons, which may be of great importance where the proton acts as a catalyst. However very high pressures add other factors, as has been indicated above, which are at present still not fully understood and which modify the trend in proton mobility.

TABLE 1. Dissociation of Weak Acids and Bases

Reference		$K_p \times 10^5$ (at 25°C) P = 1 atm.	P = 3000 atm.	K_{3000}/K_1
11	Ammonia in water	1.75	24.3	13.9
12	Acetic acid in water	1.71	5.38	3.5_8
12	Formic acid in water	17.3	41.8	2.4_2
18	Picric acid in methanol	26.4	224	8.5
12	Piperidine in methanol	0.61	12.6	20.7
		$K_p \times 10^5$ (at 45°C) P = 1 atm.	P = 12,000 atm.	K_{12000}/K_1
12	Ammonia in water	1.93	1010	523
12	Piperidine in methanol	0.28	300	1070

In the case of methanolic solutions of a strong acid such as HBr, the excess proton conductance decreases with increasing pressure. This indicates that the hindering of rotation of the solvent molecules into a position favourable to proton transfer plays a predominant part. The conductance of a base in methanol, such as sodium methoxide, has the same conductance-pressure characteristic as a methanolic solution of a salt, which indicates that no proton transfer mechanism occurs. In contrast, therefore, to the effect of pressure on a proton in aqueous solution, in methanolic solution pressure reduces its mobility. This influences the behaviour of a proton catalyst in a high-pressure system.

The generalisations made above all apply to solutions at room temperature. In recent years FRANCK, in Göttingen, has been investigating the conductance characteristics of acids, bases and salts in superheated steam. Steam at high density is a fairly good solvent for quartz and salts of certain alkali metals, some of which behave as electrolytes in the dense vapour phase. This information is of vital importance both to geophysicists, to whom it may explain some of the theories of rock formation, and to boiler engineers who are interested in the corrosion of superheater tubes. FRANCK has found that the conductances of dilute KCl solutions are increased to ten times their value at room temperature in superheated steam at temperatures of 500°C and steam densities of 0.5 g./cm³. The values for KOH and HCl are somewhat lower. At these high temperatures these compounds, which are totally dissociated at room temperatures, are associated to a considerable degree, and the proton transfer mechanism accounts for only a small part of the conductance in the cases of KOH and HCl.[17]

Weak Acids and Bases: In the solution of a weak acid or base, and this includes nearly all organic acids, such as acetic and the other fatty acids, and organic bases such as the methylamines, an equilibrium exists between the ions and the undissociated acid or base. It has been pointed out, in discussing equilibria, that pressure favours the ionised form (see Fig. 2). At high pressures two competing effects determine the conductance: the increased ionic strength of the electrolyte and the reduced mobility of the ions. The former effect is usually predominant and explains the large increases in conductance frequently observed.

(To be continued)

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LARGE-SCALE FREEZE-DRYING EQUIPMENT FOR FOODSTUFFS

Process costs for freeze-drying food can be made competitive with those for preserving by canning or freezing. Trends in design of these driers are described in this article.

by JAMES C. FORREST, B.Sc., A.M.I.Mech.E.

IT has long been agreed that vacuum-dried foodstuffs are in almost every respect superior to those which are dried in heated air. The two main reasons for this are that the product is processed in an atmosphere with a very low oxygen content and, secondly, that the flesh temperature is maintained at a relatively low value, thus ensuring that oxidative deterioration of the product will be minimised. This advantage is even more pronounced if the removal of moisture is effected from the solid-ice phase (i.e., in freeze-drying) in that there is no shrinkage of the material, practically no change in taste, texture or colour, and reconstitution of the dehydrated product is in most cases almost instantaneous. In addition, the product will stand prolonged storage at ordinary temperatures, provided it is packed in a material which is impermeable to moisture and oxygen.

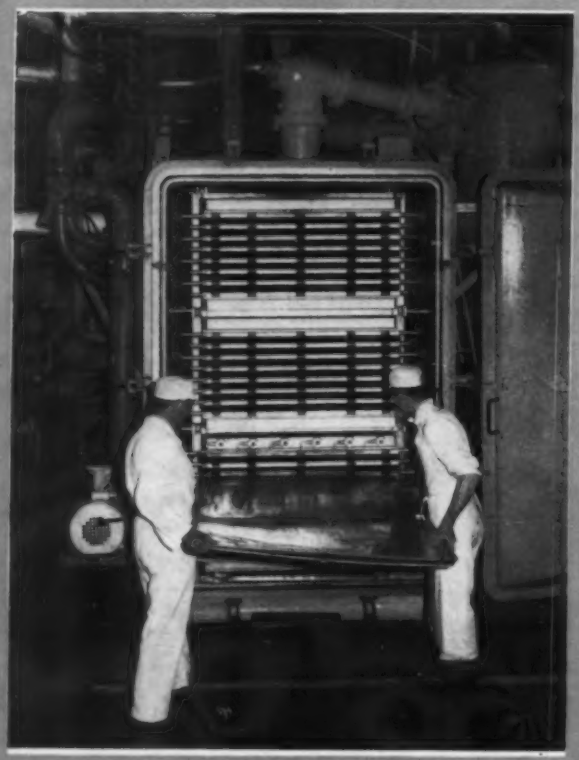

Fig. 1. End view of cabinet showing heating water circuit on the left with vacuum augmentor discharging to spray condenser on top.

While these features have been appreciated for some time, the process has not so far been commercially developed for economic reasons. In the past, freeze-drying has been applied to commodities such as blood plasma, pharmaceutical and similar products where the oncost attributable to the expensive dehydration equipment was relatively small as compared with the value of the raw material. A similar design of equipment was employed in the early experimental work carried out on meat at the Low Temperature Research Station, Cambridge,[1] where drying times exceeded 24 hours were required. Under these conditions, the high processing costs involved outweighed the advantages previously mentioned, and resulted in a product, which, although acceptable, could not compete economically with other forms of preservation. Recent developments, however, have resulted in a marked reduction of the drying times required, while still maintaining a comparable quality of product, and a preliminary survey has shown that the process costs involved are roughly comparable with those in the canning and freezing industries when such factors as storage and transport are considered.

Dehydration Equipment

A cabinet-type drier (Fig. 1) has been used in the recent work which operates on the vacuum contact-plate system and was manufactured by A/S Atlas, Maskinfabrik, Copenhagen. This equipment has been fully described elsewhere.[2] It consists of a series of horizontal, hollow, water-heated plates, of labyrinth construction, linked

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together in such a way that the spaces between adjacent plates can be varied, whilst still maintaining equal space widths between plates throughout the stack. This assembly, which is hydraulically actuated, is housed in a robust cabinet with an access door at both ends, and the system can be evacuated by two water ejectors, drawing non-condensible gases from the top of a spray condenser, into which two steam augmentors discharge. The heating water system, which can be pressurised, consists of a circulating pump which passes the water through a steam-heated calorifier and change-over valve to the heating plates. The purpose of the valve is to reverse the direction of flow in order to even out the effect of the temperature difference which exists during the early stages of the dehydration cycle between the plate inlet and outlet connections.

The material to be dried is loaded on an 8 ft × 4 ft aluminium tray, covered with a sheet of similar material, and this in turn is loaded into the space between two heating plates. The plates are arranged in three banks with eight plates in each bank, the top and bottom plate being reinforced by a sturdy framework to withstand the applied load with a minimum of deflection on these plates. As the remainder of the plates are not so strengthened, it is necessary to fill all the spaces in each bank, i.e., seven trays, if undesirable buckling of the plates is to be avoided, and in practice the cabinet can be operated at either one-third, two-thirds or full load, depending on the product.

Physical Considerations

The equipment was originally designed to dry one ton of fish fillets down to 15% moisture content in about 7 hours; after compression of the mat of partially dried fillets, the resulting blocks were further dried to a moisture content of about 5%. The evacuating equipment was intended to maintain a pressure of about 10-15 mm Hg. in the cabinet during the initial stages of drying, but towards the end of the cycle this dropped to between 2 and 3 mm Hg. and, obviously, under these conditions it was impossible to freeze-dry the product.

The vapour pressure of pure ice at 0°C is 4.57 mm Hg., and to sublime pure ice to water vapour the partial pressure of water vapour in the system must be below this value. Foodstuffs invariably have a substantial amount of salts and sugars present, which, at the triple point of their solution in water, exert a vapour pressure which is even lower than that of pure ice. It became apparent that, to ensure no thawing of the product, an absolute pressure in the system of 1½-2 mm Hg. was desirable. Subsequent tests showed that this condition could be obtained by reducing the loading and the rate of heat input, and by removing the non-return valves between the water ejectors and the spray condenser. These non-return valves were of heavy construction, and were fitted to prevent water being drawn back into the condenser in case of failure of the water pump, but, due to their weight, they introduced an appreciable resistance to the flow of non-condensible gases from the system.

The advantage of the vacuum contact-plate method over conventional shelf driers is that heat is conducted into the material through top and bottom surfaces simultaneously, and, provided the product is cut to a uniform thickness, good thermal contact between heating plates and the material surfaces can be obtained. The plate contact pressure must be carefully controlled, since the two requirements for rapid removal of moisture are directly opposed. A maximum heat flow to the foodstuff and the minimum resistance to the flow of vapour outwards cannot be realised simultaneously, since the former depends on a high plate pressure, while the latter will be seriously affected by this condition, as the bulk of the drying takes

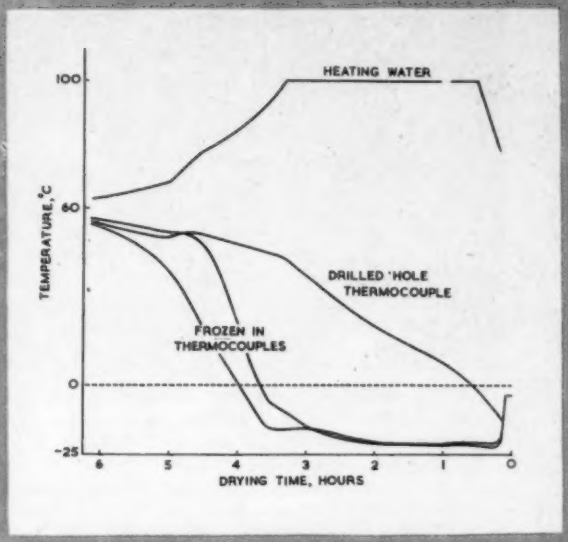

Fig. 2. The effect of the method of inserting thermocouples on the indication of material temperatures.

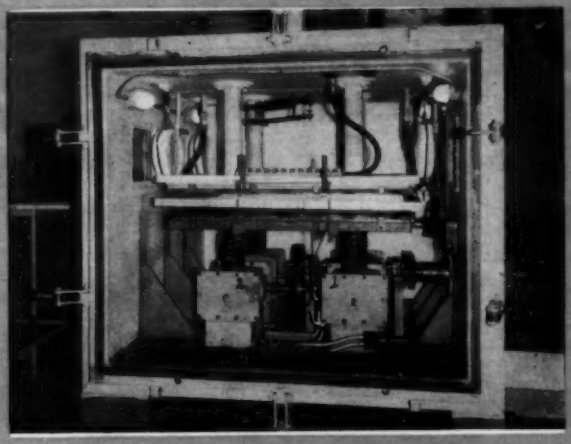

Fig. 3. Vacuum cabinet fitted with one pair of heated plates. The lower plate is raised by four screw jacks, and four scales are provided opposite the windows to permit weighing of the product without breaking the vacuum.

Fig. 4. Pre-frozen cod cutlets loaded on an expanded aluminium sheet, supported by a stiffened aluminium tray and covered with a second expanded aluminium sheet.

place from the contacting faces. This may result in the generation of a relatively high pressure within the piece of material, which, in freeze-drying, will cause local thawing and an inferior product.

Instrumentation

The progress of the dehydration cycle is judged by the temperature of the foodstuff, since, as long as water vapour is being evolved, the necessary latent heat of evaporation must be supplied by the tissue of the material which will consequently be at a lower temperature than the heating water in the plates. Towards the end of the cycle this temperature difference decreases, and the material is removed from the cabinet when the temperatures attain the same value, usually about 60°C.

Copper-constantan thermocouples are used for this purpose connected by a plug and socket assembly inside the vacuum cabinet to a multi-point electronic temperature recorder mounted on the control panel. Some misunderstanding has arisen in the past as to the actual temperature of the foodstuff being processed due to inaccuracies in thermocouple readings arising from two main factors. First, when freeze-drying, the thermocouple junction will be in contact with frozen material which may be at −10 to −20°C, while a short distance away the cable is in contact with the surface of the heating plate at a temperature of 90-100°C. If a wire of fairly large cross-section is used, the heat conducted along the wire to the junction can cause appreciable errors, not only by raising the temperature of the junction above that of the surrounding tissue, but also by supplying latent heat to the ice surrounding the thermocouple. This forms a sleeve of dried material, the temperature of which will not be representative of the whole piece. The second cause of errors is the method used to insert the thermocouple into the material in the first instance. If the foodstuff is dried without prefreezing there is no problem, as the wire is merely pushed into the soft flesh, but this cannot be done with a hard block. Here recourse has to be made to some method of pre-forming the hole required, either by drilling, or inserting a metal skewer which is later removed after freezing. It is, however, extremely difficult to ensure that the junction is contacting the material, since the thermocouple must be a good fit if a sleeve of dried material is not to be formed, as explained above.

When drying thick pieces of meat and fish, usually about 15-18 mm, the raw material is frozen as joints or blocks and then cut into slices either by guillotine or band saw. In practice, it has been found that the best results are obtained when the thermocouples are inserted into the raw material before the freezing operation (Fig. 2), and, to minimise the danger of accidentally severing the wires, they are kept as short as possible (6 to 8 in.) and fitted with a socket connection. The wire used is 33 s.w.g. copper-constantan with woven glass-fibre insulation, and to facilitate insertion into the raw flesh it is stiffened by a thin coating of a cold-setting cement. The recorder used has 16 points. Two thermocouples are used for reading the inlet and outlet water temperature in the heating plates. The remaining 14 points can be used for flesh temperatures, giving a fairly representative indication of the variation in temperature throughout the complete load of material.

Accurate measurement of absolute pressure in the system raises some problems in the region of 1 to 2 mm Hg. due to the fact that this is made up of a number of partial pressures, namely, air, water vapour and various volatile constituents of the foodstuff being processed. The proportion of volatiles present is small as compared with the air and water vapour, but it does preclude the use of a PIRANI type gauge and some types of ionisation gauges due to possible contamination of the element. A simple MCLEOD gauge is also unsatisfactory, since the condensible components give rise to errors; a method can be employed using this type of gauge in conjunction with a cold trap, but it is not suitable for use by unskilled labour. A type of ionisation gauge using radium as a source of alpha particles has been obtained, which, if contaminated, can be easily cleaned without affecting the accuracy of the instrument. In addition, the fact that the calibration curves for air and water vapour lie closely together overcomes the need to determine the relative amounts of these two components which are present.

A further check on the partial pressure of water vapour can be made by suspending inside the cabinet an icicle of pure ice into which a thermocouple has been frozen. The icicle reaches equilibrium at a temperature corresponding to the partial pressure of the water vapour. This would probably be the simplest method to use in a commercial drier, where the ratio of air to water vapour concentrations would probably be fairly constant in successive runs. Other instruments fitted to the unit are flow meters, to measure steam supply and rate of water circulation, and ammeters on all the ancillary electric motors.

With these instruments most of the physical variables in the process can be measured and controlled, but one unknown does exist. This is the pressure actually being applied to the foodstuff. Although theoretically the hydraulic pressure applied to the plate movement mechanism should give an indication of the pressure on the foodstuffs, this is not the case because the frictional resistance of the linkage cannot be assessed. To obtain a reproducible product in the present equipment it is necessary to know the position of the plates relative to the material at corresponding times on successive runs, and for this purpose a plate spacing indicator is fitted. This method is fairly successful, but the degree of pressure applied has a marked effect on the rate of drying. A small vacuum drier (Fig. 3) with two heating plates each 4 ft square has been constructed and fitted with a means of studying this feature. The pressure is applied to the foodstuff by four screw jacks which raise the lower heating plate against a fixed heating plate, and load cells are mounted above each jack to measure the forces applied. The cells consist of steel proving rings which distort under axial load, and the degree of distortion is measured by strain gauges, the load being indicated on an instrument outside the cabinet. Some considerable difficulty was experienced in obtaining cells which were unaffected by variations of atmospheric pressure, but the fault was eventually traced to the fact that wire strain gauges were used in which air bubbles had been trapped in the adhesive bonding the wire to the backing strip. Expansion of these bubbles under vacuum caused local distortion of the wire of the gauge, resulting in a variation of indicated load, but the use of etched foil gauges has given good results. Tests are at present being made on this equipment to study the effect of contact pressure between the heating plates and the foodstuffs in order to determine how critical this variable is.

Process Procedure

The pretreatment for large-scale vacuum drying varies for different foodstuffs[3, 4, 5, 6, 7, 8, 9] depending on the nature of the material and whether it is desirable to dry from the frozen state. Tests have been made on a number of foods to determine whether evaporative freezing in the vacuum cabinet is acceptable, or whether some form of prefreezing is necessary. Depending on the initial moisture content, temperature and analysis of the foodstuff, 10-16% of the water present must be evaporated in order to freeze the remaining free water in the material, and if this pro-

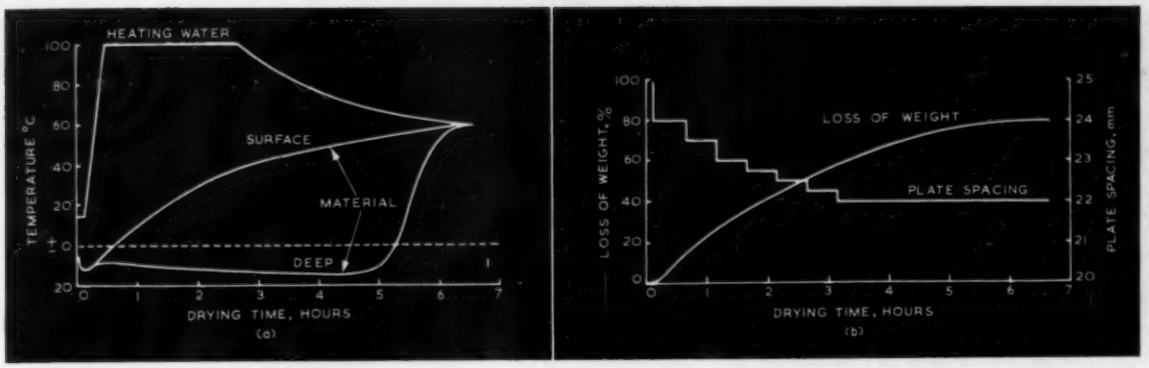

Fig. 5. Physical conditions during drying of 17-mm-thick cod steaks on expanded metal in vacuum contact plate system.

portion of water is contained in a surface layer, e.g., in granular materials such as meat minces, evaporative freezing will be successful. With larger pieces, such as meat and fish steaks 18 mm thick, this is not the case. If no pre-freezing is used, attempts to cool the product by evaporation result in the formation of a glossy outer skin, which slows the drying operation and retards the absorption of water on reconstitution.

The reason for this is that some drying of the tissue takes place from the liquid phase in the outer layers, causing migration of solids to the surface, denaturation of the protein and local shrinkage. This effect can be reduced by dipping in water before drying, but it is difficult to eliminate it completely. The water dip appears to assist in two ways. It provides some free water on the surface and washes off some of the solids which exude from cut cells on the surface of the product.

This is not, however, the only factor which decides whether or not the foodstuff should be frozen before spreading on the drying trays. With some materials it is very difficult to obtain uniform slice thickness without pre-freezing. This is especially apparent with meat and fish, where the unfrozen flesh is soft and pliable, and it is impossible to pass a knife through it without distorting the piece and consequently making an uneven cut. The simplest way to overcome this difficulty is by lowering the temperature until the product is sufficiently rigid to handle, when slices can be produced either by guillotine or bandsaw. Freezing is carried out in an air blast freezer, which is being modified at present to examine the effect on the final product of different freezing rates. In parallel with this, equipment is in hand to permit immersion freezing in sealed moulds.

Another requirement of major importance is the direction in which the material is cut relative to the muscle fibres in the flesh. Meat and fish flesh cut across the fibres will dry much more quickly than when the fibres lie parallel to the surface, since the resistance to vapour flow is less in the direction parallel to the muscle and this type of cut reduces the length of the vapour path. During slicing the product tends to thaw, and the slices have then to be re-frozen before loading into the vacuum cabinet. The temperature of the foodstuff after this operation is critical, since some time may elapse before the cabinet is sealed and the absolute pressure is reduced to a level where evaporative cooling can maintain the material in the frozen state. Over this period the product is resting on the heating plate. This is at a relatively low temperature at this stage (about 10°C), but can nevertheless pass an appreciable quantity of heat to the frozen material, resulting in thawing of the surface tissue.

Dehydration

The procedure which has been adopted for animal products has been fully described elsewhere,[5, 9] but a recent innovation is worthy of note. It is probably one of the most important single advances in the vacuum dehydration of foodstuffs in recent years in the United Kingdom.

When perfectly flat pieces of frozen material are placed on a heated shelf under vacuum the product is not in contact with the shelf, but resting on a cushion of high velocity water vapour escaping from the tissue. Similarly, with the contact-plate method, this condition would be apparent on both top and bottom surfaces. In the early stages the rate of escape of water vapour is the controlling factor in the rate of drying, so that some means of reducing this resistance to vapour flow would be beneficial. The rate of heat transfer to the product is also affected by the water vapour layer, as heat can be conducted to the product only through the protruding tissue in contact with the heating plates. A proportion of the heat will be transferred by radiation, but this will not be appreciable since the plate temperature is relatively low. The use of a matt black finish on the drying trays, instead of the normal polished aluminium, appears to make no significant difference to the drying rate.

If a piece of expanded aluminium sheet is placed between the product and the heating plate on top and bottom surface (Fig. 4), a series of channels is formed, separated by the mesh formation. The channels provide an escape path for the water vapour, thus markedly reducing the resistance to mass flow, while the mesh itself, being in good contact with the material, assures an adequate flow of heat to the surface of the foodstuff. Moreover, since the points of the expanded sheet form indentations on the surface, some penetration of the dry layer of material is achieved. Using this equipment the drying time for 15-mm-thick cod steaks is reduced from 10½-11 hours to 6½-7 hours. The modified process is as shown in Fig. 5.

Alternative Heating Methods

Comparison of various methods of applying heat during freeze-drying[10, 11] shows that the rate of drying of foodstuffs is lowest with shelf heating, and becomes progressively greater with contact-plate heating, radiant heating and high-frequency dielectric heating. The difference in drying times using the second and third methods is reported to be small, but depends on the thickness of the material, since some penetration of the dried outer layer is achieved with radiant heat and with thin slices this advantage is proportionately greater.

Radiant Heat

Some experimental work has been done at the Experimental Factory to determine whether this method can be developed to give a faster rate of drying than the contact-plate method. A small pilot heating frame has been used in this work, employing commercially available fused quartz tubes with nichrome wire heating elements, and encouraging results have been obtained. The greatest problem is the control of the surface temperature of the product, but the use of a number of thermocouples located just under the outer layer of tissue has proved successful.

The ideal arrangement would be to generate the bulk of the energy at a particular wavelength which would be absorbed by the moisture in the foodstuff but not by the dry tissue in the product. Future work will be aimed at varying the temperature of the element by using different gauges of nichrome wire at the same power value per unit area of material surface to assess the optimum conditions for maximum heat penetration. The results of recent work on fish steaks 16 mm thick have shown that the rate of drying by this method is comparable to that achieved with contact-plate heating using expanded metal inserts, but this rate may yet be improved.

High-frequency Heating

Theoretically, this system is attractive, since ice has a higher dielectric constant than dry tissue and will therefore be preferentially heated in a high-frequency alternating field. However, at the low absolute pressures required for freeze-drying, there is a grave danger of ionisation of the residual gases, leading to a coronal discharge and local scorching of the surface of the product. The use of ultra-high frequencies (about 2450 Mc/s) is reported to overcome this difficulty,[12] and it is hoped to study this method in Aberdeen, but past work using a 20-Mc/s generator has shown that control of the heat input can be critical. This equipment was used to dry a variety of foodstuffs from about 10% moisture content on the wet basis to about 5% at a pressure of about 20 mm Hg. With this method heat is generated within the mass and it was often found that the centre of the product was scorched though there was no visible damage on the surface. From this aspect, the control of a large-scale drier might be difficult, as the introduction of thermocouples to measure internal temperatures leads to local distortion of the applied high-frequency field, giving readings which are not representative of the bulk of the material. However, the reduction in drying times which can be achieved by this method makes it worthy of further study. Since the cost of the process is reported to be reasonable on a pilot scale, it may be that the technique will be applicable to commercial dehydration of relatively expensive foodstuffs such as meat and fish. It is doubtful whether it would be economical to carry out the entire process by this method, but if an electrical heating system is desirable the use of radiant heat in the early stages, followed by dielectric heating, might be advantageous.

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Du Pont's Development Laboratory

A NEW modern laboratory devoted to development work on neoprene and other synthetic rubbers and rubber chemicals for the European rubber industry was officially opened recently by the Du Pont Co. (United Kingdom) Ltd. at Hemel Hempstead. The laboratory, to be known as Elastomers Research Laboratory, is the first permanent facility to be completed by Du Pont in Europe and is under the management of Wilfred P. Fletcher. Du Pont also have a neoprene plant nearing completion in Londonderry, Northern Ireland, and the aim of the laboratory will be to find new applications for neoprene produced at Londonderry, as well as assisting customers to use the product advantageously, said Mr. W. H. McCoy, managing director of the company. "Functionally," he said, "they complement each other." The Londonderry plant is due to start production in the first half of 1960.

The 10,000-sq.-ft laboratory is equipped with the most modern instruments and testing devices from the United Kingdom, France, Germany and the United States—equipment which can accurately duplicate most of the processes used by rubber manufacturers throughout the world.

The laboratory is divided into three main parts: dry processing, fluid processing and physical testing. In the dry processing area, where solid rubber compounds are processed, one of the most interesting pieces of equipment is a high-pressure wire vulcanising unit which simulates continuous vulcanising conditions used in the wire and cable industry. It consists of a steam chamber 12½ ft in depth for vulcanising at steam pressures of 100 to 275 psi and a water chamber for cooling at the same pressures. Before vulcanisation, an extruder covers the wire samples with compounds of neoprene or "Hypalon" synthetic rubber.

The physical testing area is equipped with an extremely accurate and complex electronic load-measuring tester as well as one of the latest types of weatherometers developed in Germany which can duplicate almost any type of condition from intermittent rain and high humidity to dry or humid sunshine, one day of test in the weatherometer being equal to one year of natural weather conditions. This machine, the only one of its type in the country, will be used to test the weathering of rubbers under accelerated conditions. The laboratory, which is on a 5-acre site, is so designed that it can be expanded as required.

Speaking of his company's plans for future expansion in Britain, Mr D. H. Conklin, chairman of Du Pont (U.K.) Ltd. and international director in Europe of E. I. du Pont de Nemours & Co. Inc., said: "We believe there will be additional manufacturing opportunities for us in the United Kingdom and other parts of Western Europe, and we are actively studying various possibilities for local manufacture of some of our other chemical products. We cannot be any more definite about those possibilities at present, but the final decision on any one of them will depend entirely on the market situation. Each of our present plant sites, especially the one at Londonderry, is large enough for a sizeable expansion."

66.071.7

A CORRELATION FOR ABSORPTION COLUMN PACKINGS

An equation is proposed for estimating transfer-unit heights for absorption systems where the gas-phase resistance to mass transfer controls

by F. R. WHITT, M.Sc., A.M.I.Chem.E., F.R.I.C.

VARIOUS correlations of the variables associated with the effectiveness of distillation columns, packed with Raschig rings, as measured by the height of a transfer unit or equivalent theoretical plate have been proposed in the literature.[1–10] These correlations generally incorporate features unattractive to a designer handling them for the solution of a general case. The application of the more complicated equations can involve the necessity of making estimates of secondary quantities, such as flood points or diffusion coefficients, which estimations are themselves subject to error. Flooding velocities, in particular, are difficult to predict under some circumstances, such as for operations at lower than atmospheric pressure. The author[11] has discussed published data concerning this aspect of distillation column operation.

An attempt to devise an easily usable correlation of *H.E.T.P.* values with operation variables is described by the author.[9] The application of the proposed equation does not involve any detailed knowledge of the shape of the equilibrium diagram or of the more difficultly estimated physical properties of the components of the distillation system involved.

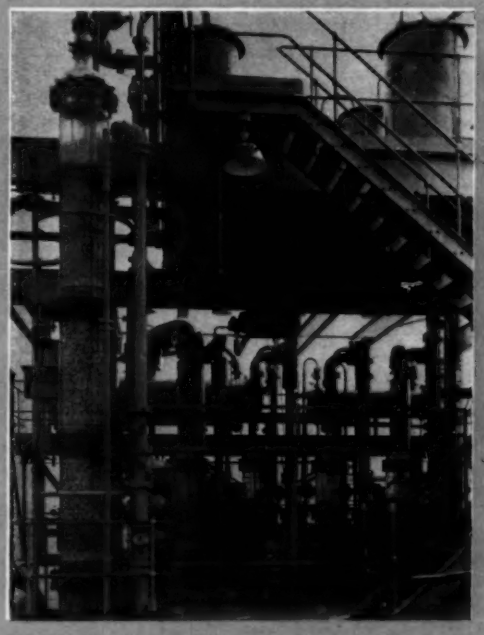
Examination of the plots presented by FURNAS and TAYLOR[1] shows that only moderate success has been achieved in correlating *H.T.U.* data. ROBINSON and GILLILAND[2] (page 466) acknowledge that a several-fold variation is possible from the value predicted by an equation proposed for *H.E.T.P.* values. The scatter of the points on a plot presented by PETERS[7] is of the same magnitude. Considering the limited number of variables incorporated in the equation proposed by CARSWELL,[8] it is improbable that close prediction of *H.E.T.P.* values could be expected from its use for a general case. The scatter of the points (±40%) on the plot presented by HANDS and WHITT[9] thus appears to be reasonable compared with that accepted in general for other correlations.

Absorption Columns

There appears to be less information published in the literature concerning the correlation of the performance of absorption columns, in general, than there is for distillation columns. SHERWOOD and PIGFORD[12] have devised a plot to correlate the $H.T.U._G$ values associated with several columns and systems. The extent of the scatter of the points on the plot is similar to that associated with distillation work recorded in the literature.[1–10] MORRIS and

Symbols Used

$H.E.T.P.$ = height equivalent to a theoretical plate, ft;
$H.T.U.$ = height of a transfer unit;
$H.T.U._G$ = height of an individual gas phase transfer unit, ft;
$H.T.U._{OG}$ = height of an overall transfer unit measured in gas units;
L = liquor rate, lb./(hr) (sq. ft), empty column;
μ = viscosity of liquor, lb. ft hr units;
μ' = viscosity of liquor, centipoise;
d = diameter of Raschig rings, ft; and
d' = diameter of Raschig rings, in.



HCl absorbers with packed tower in foreground, on a chlorobenzene plant. (Photo: I.C.I. Ltd.)

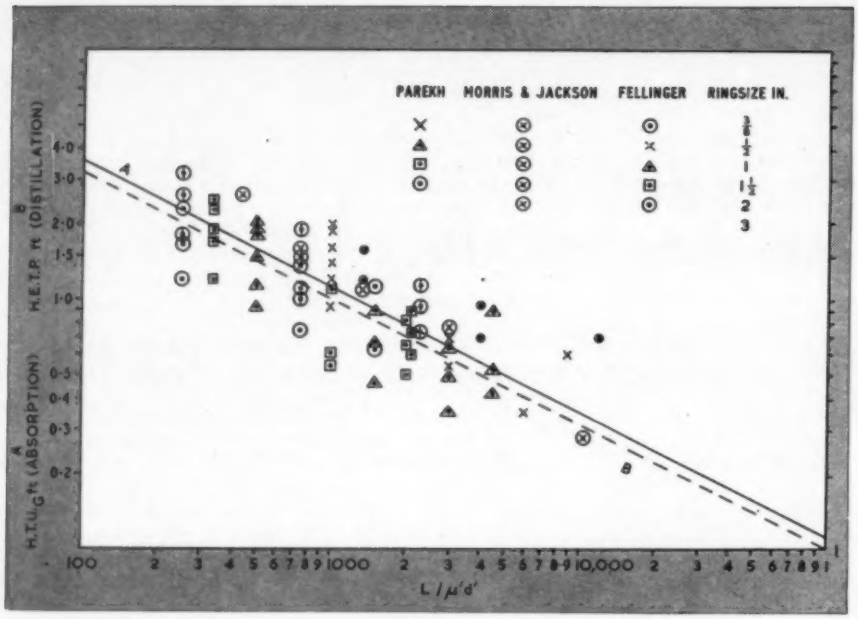


Fig. 1. A plot of H.T.U.$_G$ *versus* L/u'd' *based on published absorption data. Line* A *is the line through absorption results; line* B *is for previously obtained* H.E.T.P. *values.*

JACKSON[14] give tables of recommended *H.T.U.* values for absorption columns associated with certain conditions of operation. Detailed experimental data leading to the selection of these recommended values are not published, however.

In view of the above situation, it was thought worth while examining some of the more accessible absorption data given in the literature[12, 13, 14] on the lines used for examining distillation data.[9] The object in mind was to devise, if possible, a simple correlating equation which could be applied easily by a designer to a general case. The investigation was limited to examples of the less complex absorption systems, i.e., gas-phase controlled systems, and to be consistent to the *H.T.U.*$_G$ values reported for these systems. It was assumed, however, that for practical design purposes *H.T.U.*$_G$ and *H.T.U.*$_{OG}$ values would be interchangeable in connection with gas-phase controlled absorption systems of common occurrence in industrial practice.

Absorption Column Performance Data given in the Literature

SHERWOOD and PIGFORD[12] (page 284) give *H.T.U.*$_G$ data associated with ammonia absorption in packed columns (experimental work done by FELLINGER). MCADAMS[13] (page 289) gives data for air humidification (experimental work done by PAREKH). These recorded data were examined and a number of deductions made for several sizes of Raschig rings. Table 1 is an example of the method used for analysing the data. Similar tables were constructed for other sizes of rings. MORRIS and JACKSON[14] (pages 64 and 67) give *H.T.U.*$_G$ values for absorption columns operating under certain conditions. The minimum wetting rates for liquor flow, quoted in this reference, have been converted into the common form, of lb./(hr) (sq. ft) empty column, used by the other workers. Table II shows the results obtained from analysing the data for several sizes of Raschig rings. It was assumed, in the case of the air humidification work of PAREKH, that the system was one with a negligible liquid film effect so that *H.T.U.*$_{OG}$ value results reported could be used as *H.T.U.*$_G$ values on a general correlation plot.

Correlation of Data

A plot, on the lines of the *H.E.T.P.* plot for the distillation work given in the literature,[9] was made using *H.T.U.*$_G$ absorption data (see Fig. 1).

An average line representing the equation,

TABLE I

Ring Size in.	*H.T.U.*$_G$ ft.	L lb./(hr) (sq. ft)	$\frac{L}{\mu' d'}$	Vapour Velocity lb./(hr) (sq. ft)	Origin
1½	0.62 0.55 1.1	1500	1000	200 400 700	PAREKH
1½ *	0.92 1.2 1.5	1500	1000	200 400 800	FELLINGER
1½	1.1	2020	1350	172–810	MORRIS and JACKSON

* *To avoid confusion of points, these are not plotted on Fig. 1.*

TABLE II

Ring Size in.	*H.T.U.*$_G$ ft	L lb./(hr) (sq. ft)	$\frac{L}{\mu' d'}$	Vapour Velocity lb./(hr) (sq. ft)	Origin
3	2.6	1300	433		
2	1.6	1500	750		MORRIS and JACKSON
1½	1.1	2020	1350	172–810	(Min. Wetting
1	0.79	2990	2990	(0.64-3.0 fps, see p. 35)	Rate of rings 0.85) cu.ft/(hr)(ft)
½	0.28	5310	10260		See p. 22 and p. 64

$$H.T.U._G = 36/\sqrt{\frac{1}{d'}\frac{L}{\mu'}} \quad \ldots.(1)$$

$$\text{or } 79/\sqrt{\frac{1}{d}\frac{L}{\mu}} \text{ lb. ft hr (consistent units)} \quad \ldots.(2)$$

is drawn through the points as line *A*. The average line from Fig. 4 of Reference 9 is reproduced as line *B*. The equation for this latter line is:

$$H.E.T.P = 70/\sqrt{\frac{1}{d}\frac{L}{\mu}} \text{ lb. ft hr (consistent units)} \quad \ldots.(3)$$

It thus appears that a correlation of $H.T.U._G$ values for absorption column performances can be obtained in a similar manner to that used for correlating *H.E.T.P.* values associated with distillation column performances.

Examination of the graphical bases[15, 16] for the construction of equivalent theoretical plates and transfer units on an equilibrium diagram shows readily and visually that the concepts are interchangeable if the operating and equilibrium lines are parallel. For practical distillation operations, covering a fair amount of the equilibrium diagram, some departure from strict parellelism is allowable. Detailed examination of data conveniently assembled by STRUCK and KINNEY[17] shows that when five upwards theoretical contacts are required for a given distillation operation the number of transfer units required differs by only a few per cent from the number of equivalent theoretical plates. Thus it may be reasonably assumed that for the work described in References 9, 12, 13 and 14, which concern gas-phase controlled absorption systems, *H.E.T.P.*, $H.T.U._{OG}$ and $H.T.U._G$ values approach interchangeability.

It appears that this approximate interchangeability of transfer unit and equivalent theoretical plate, and the effect of the incorporation of the viscosity of the liquors, are sufficient to make it possible to correlate on the same plot both distillation and absorption data. The range of liquor viscosities involved was 0.35 to 1.0 centipoise.

The vapour velocities involved in the distillation data ranged from 150 to 1450 lb./(hr) (sq. ft) (empty column). The range associated with the absorption data was 172 to 810 lb./(hr) (sq. ft). As this variable is known to influence *H.T.U.* values, attempts were made to construct plots, like Fig. 1, incorporating vapour velocity quantities in the abscissæ or ordinates. The results suggested that the scatter of the points was not reduced sufficiently to justify the extra complication. MORRIS and JACKSON[14] (page 64) quote $H.T.U._G$ values recommended for use if the gas velocity is within a certain economic range from the point of view of pumping costs. This is equivalent to neglecting the effect of gas velocity for practical purposes. In contrast the effects of variables such as liquor velocity (see Reference 18) and ring diameter are much more important. These variables, consequently, have been incorporated in Equation (1) and its equivalents.

General experience has shown that, for good liquor distribution in packed columns, packed heights, without redistributors, should not be more than 10 ft. It is also accepted that the ratio of tower diameter to ring diameter should exceed 8:1. These criteria were satisfied by the dimensions of the distillation and absorption columns associated with work described in Refs. 9, 12, 13 and 14.

Conclusions

Examination of data given in the literature concerning the performance of absorption columns show that an Equation (2) will correlate $H.T.U._G$ values and the main operating variables. This equation, which is dimensionally consistent, resembles closely one[9] previously proposed for the correlation of *H.E.T.P.* values for distillation columns. The data used were concerned with Raschig-ring-packed absorption columns of semi-technical size, as distinct from laboratory-scale columns. The information deduced should therefore be of use to designers of industrial size plant and supplement data provided by sources such as Ref. 14.

A scrutiny of the literature concerned with the correlation of *H.T.U.* or *H.E.T.P.* values and operation variables shows the complexity due to the number of phenomena involved. It appears improbable that great accuracy of correlation could ever be embodied in any equation, which at the same time had a general practical applicability. It would appear logical, however, to make use of the various correlation equations proposed in the literature before resorting to random selection of *H.E.T.P.* or *H.T.U.* values from general sources of information as exemplified by Refs. 19 and 20.

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Gas from Coal or Oil?

IN HIS RECENT presidential address to the Institution of Gas Engineers, Mr. E. M. Edwards, deputy chairman of the Wales Gas Board, said that the full development of the gas industry must be based on coal. The reason he gave for this premise was that forecast world reserves of coal are greater than those for oil.

However, Mr. A. E. Wiggins, Supply and Planning Co-ordinator, The Shell International Petroleum Co. Ltd., in a paper presented at the Baltic and International Maritime Conference held recently in London, would seem to disagree with Mr. Edwards, as he states that the proven reserves of oil have more than kept pace with extraction. For every barrel of oil removed from the earth, more than one is discovered; the rate of proven reserves o production is constantly growing. By 1975, states Mr. Wiggins, oil and natural gas would be dominating the energy pattern. Outside North America its total share is expected to be nearly half. The use of natural gas is growing and its use could improve the competitive ability of the gas industries of many Western European countries. Only a few months ago, he said, a special ship reached this country from the United States with a cargo of liquefied methane for experimental use (by the gas industry).

The shipment of liquefied methane (2000 tons) referred to by Mr. Wiggins was passed through the Romford Gas Reforming Plant in the early part of this year. This plant is capable of producing over 50 million cu. ft a day of consumer gas from refinery gas with an operating staff of only four men and is producing some of the cheapest gas at present being made by the NTGB.

Economically, therefore, it would seem that oil has more to offer the gas industry than coal: from the air pollution aspect alone, gas reforming plants have a decided advantage over traditional gas plants.

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Fig. 1. General view of main flow circuit.

A METHOD OF EXAMINING FLOW OVER FINNED TUBES

A novel technique for the study of flow patterns set up by a fluid flowing parallel to radially-finned tubes

by A. ATHERTON, B.Sc.

THE use of extended surfaces to facilitate heat transfer is a well-established engineering practice. With the advent of the atomic pile and the realisation of its potentialities as a source of power production, research has proceeded on a large scale in attempts to evolve improved heat-transfer systems along these lines. The use of finned surfaces to improve the efficiency of extraction of heat from the core of a nuclear reactor is particularly promising in the case of the gas-cooled type, although there is considerable difficulty in its application. The solution to this very practical problem has been sought largely by experiment, because the rapid rate of nuclear power plant development in recent years could not await the completion of a long-term programme of fundamental research on such a complex topic.

The design of fuel elements and their cooling surfaces must take into account many factors. A compromise must be reached taking into account metallurgical and neutron absorption properties, the needs of structural design and the economics of large-scale fabrication. It is naturally a major aim to produce a favourable balance between the useful power abstracted and the frictional losses involved in circulating the coolant.

ANDERSON[1] has reviewed these conditions for several

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Symbols Used

a = constant;
d = fin diameter;
d_o = fin-root diameter;
D = channel internal diameter;
f = functional representation of "ideal" pulse;
F = functional relationship between Stanton, Reynolds and Prandtl numbers;
h = distance across fin-space;
m = mass-transfer coefficient;
M = dimensionless mass-transfer coefficient;
n = normality of electrolyte in fin-space under equilibrium conditions;
N = normality of electrolyte feed solution;
Q = rate of electrolyte feed;
Q' = rate of influx of fluid from channel to fin-space;
Q'' = rate of efflux of fluid from fin-space to channel;
t = time;
t_m = mean residence time;
v = velocity of flow at fin-tip normal to fin;
V = volume of observation sector;
Pr = Prandtl number;
Re = Reynolds number (referred to free annular space of channel);
St = Stanton number (referred to fin-enveloping cylinder);
θ = angle of observation sector; and
ν = kinematic viscosity of water at room temperature.

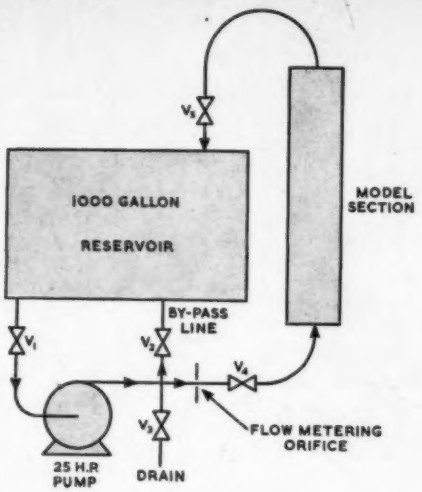

Fig. 2. Schematic diagram of main flow circuit.

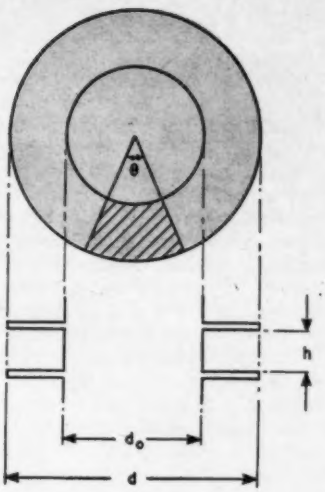

Fig. 3. Finned tube portion. Observation sector shaded.

possible geometrical configurations of fuel elements. A more detailed consideration of the particular case of heat removal from gas-cooled reactors may be found in a paper by DIAMOND and HALL,[2] and the development of the circumferential-type fin for cylindrical fuel elements, as used at Calder Hall, is outlined by FORTESCUE and HALL.[3] The latter authors draw the conclusion that this type of finning holds considerable advantage over the longitudinal pattern because it promotes good radial mixing with an axial flow of coolant. This was evidenced both by empirical measurement using air flow rigs, which indicated good heat-transfer performance, and by the use of large-scale two-dimensional models. Further studies on similar fin systems have been undertaken by KNUDSEN and KATZ,[4] who used a water model to measure the heat-transfer properties of various finned and plain tubes. They deduced that there exists an optimum value of the ratio of the volume of coolant contained by the fin spaces to the annular volume outside the fins to give maximum power performance. The greater heat-transfer capacity of finned tubes compared to that of plain tubes was again attributed to the increased turbulence generated by the fins.

The present research programme was launched with the idea of investigating in particular the flow conditions, rather than heat transfer, prevailing over transversely-finned cylinders during the axial flow of coolant, in the hope of realising a more fundamental approach to design regarding fin-geometry.

Design of Apparatus

The experimental rig was designed to incorporate a cylindrical channel carrying a coaxial finned tube over which a flow of water could be established satisfying the conditions of geometrical and dynamic similarity with the gas-flow obtaining in a typical reactor.

It was set up as a closed-circuit system (Fig. 1) consisting essentially of a reservoir of 1000 gal. capacity, a 25-hp centrifugal pump capable of delivering water at a rate exceeding 1000 gal. per min. against pressure heads up to 50 ft wg, and a channel 36 in. long and 4 in. I.D. for the model section. This channel was the same size as those used in the reactor; the upper limit of Reynolds number attainable in the model was approximately 5×10^5. The pipe fittings linking the various parts of the circuit were mainly of 5-in. nominal bore. A by-pass line was included in parallel with the model to allow the pump to work against minimum pressure head at all rates of flow and at the same time provide a more sensitive means of controlling the flow. Fig. 2 shows the layout of the system and location of the control valves.

Model Section

The model section was designed with the aims of acquiring some knowledge of the flow patterns generated by various fin geometries and the associated mass transfer using both electrolyte as a tracer to obtain quantitative measurements and also using photographic techniques. Only the former will be discussed in this paper.

The channel was fabricated from Perspex, $\frac{1}{4}$ in. thick, and fitted with flanges of standard pattern. Inside this channel was mounted the finned tube to be investigated, held coaxially by means of supports at either end. The tube was made of magnox, a magnesium alloy. The length of each finned surface was 30 in. and the diameters were all in the region of $2\frac{1}{4}$ in. The various fittings were designed for ease of assembly, since the model section was completely dismantled for each change of finned tube.

The reasons for using a full-size replica were as follows:

(a) The pumping requirements would have been prohibitively large for a scaled-up model.
(b) Photography of the narrow fin-spaces would have been difficult if the model had been scaled-down.
(c) Manufacture of finned tubes could be carried out with little modification of the normal production schedule.

Flow Metering

The rate of flow through the model section was determined by the use of an orifice plate equipped with corner tappings which were connected to a mercury manometer. The construction and installation in the flow circuit were in accordance with B.S. 1042.[5] A survey of the flow conditions in the open model channel (i.e., without finned tube) was carried out, by measuring the velocity head (using a standard pitot-static tube) at intervals along diametrical traverses, for various flow rates covering the working range of the pump. The purpose of this preliminary work was twofold:

(a) As a means of finding if there was any effect due to the bend in the pipework upstream of the model or

due to altering the setting of the gate-valve in this line.

(b) As a check on the reliability of the flow metering orifice under the rather restricted operating conditions since it was situated in only a short (5 ft) straight length of pipe.

Traverses were made both in the plane of the bend and at right angles to this plane; they showed that the velocity profiles were not influenced by the bend or the valve opening. Agreement between the value of flow rate through the channel was determined by integrating the velocity measurements, and that indicated by the orifice was better than 1% over the whole useful range of the pump.

Mass-transfer Coefficient

A dimensionless parameter representing mass transfer may be derived by considering the radial efflux of fluid from a sector-shaped element of volume contained by two successive fins (Fig. 3). The dimensions are as follows:

Fin root diameter $= d_o$
Fin overall diameter $= d$
Fin spacing $= h$
Sector angle $= \theta$

Volume of sector $= V = (d^2 - d_o^2)\theta h/8$

Consider a situation in which a constant volume Q per unit time of an electrolyte solution of known normality (N) is fed into the fin space from the root.

The volume taken for measurement is a sector lying completely within the region of the fin space over which the electrolyte is distributed. By the isolation of such a section, increased confidence can be placed in the uniformity of distribution and therefore on the measured concentration changes. In the equilibrium state the fraction a of solution supplied which enters (and leaves) this sector remains constant irrespective of the electrolyte distribution outside it. The mean normality (n) within the sector may be calculated in the following manner. Each stream velocity v at the fin-tip is associated with the influx of a certain volume per unit time, say Q', to the sector. The equilibrium state is equivalent to the net changes stated below.

	Vol./unit time	*Normality*
In	aQ	N
	Q'	O
Out	Q'' (say)	n

Two equations of continuity may now be written:

$$aQ + Q' = Q''$$
$$aQN = Q''n$$

$$n = \frac{aQN}{aQ + Q'}$$

If, at any instant, Q is reduced to zero (i.e., the electrolyte supply shut off), then the rate of efflux of fluid from the volume V is also equal to Q', so that the mean residence time, t_m, of fluid elements within V is given[6] by $t_m = V/Q'$.

Hence
$$n = \frac{N}{(1 + V/aQt_m)}$$

By analogy with heat transfer, the coefficient of mass transfer (m) over the fin-enveloping cylinder may be defined as

$$m = \frac{\text{No. of g.-mol. transferred per unit area per unit time}}{\text{Concentration difference across transfer surface (g.-mol/unit vol.)}}$$

In particular, for the sector:

$$m = \frac{aQN/\frac{1}{2}\,d\theta h}{n} = aQ\left(1 + \frac{V}{aQt_m}\right)/\tfrac{1}{2}\,d\theta h$$

The experimental conditions (described later) were adjusted to make n/N small so that $V/aQt_m \gg 1$. Under these circumstances

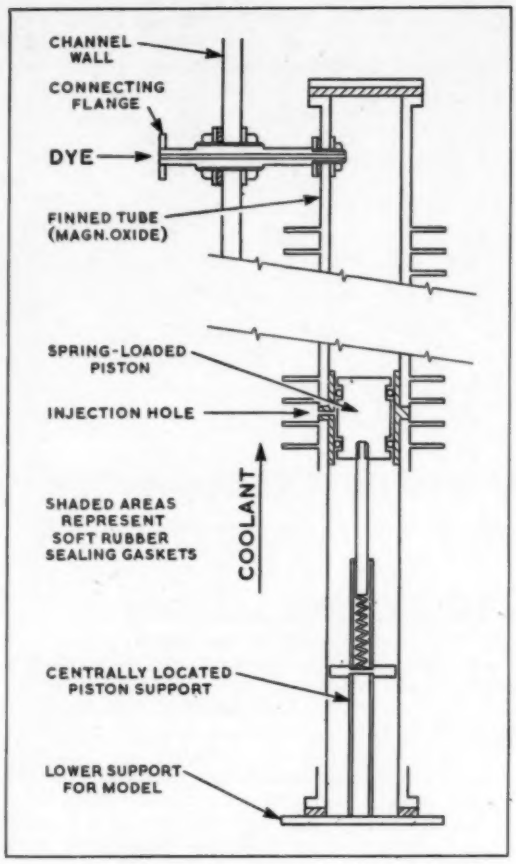

Fig. 4. Finned tube. Method of injecting electrolyte.

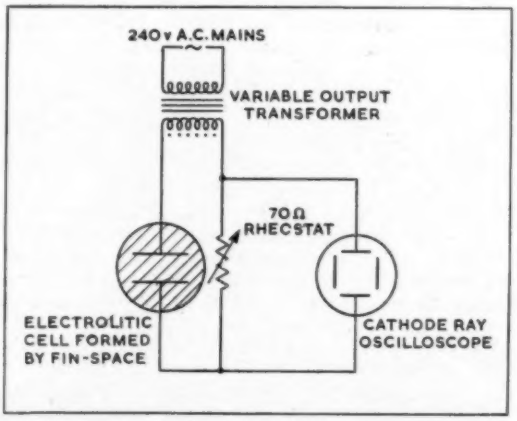

Fig. 5. Circuit for concentration measurement.

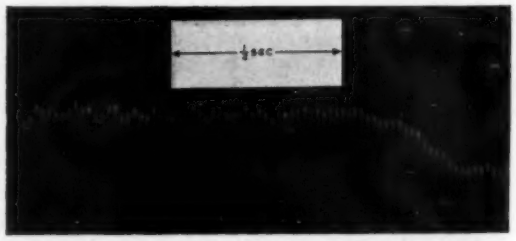

Fig. 6. CRO record of concentration changes with time.

$$m = \frac{d^2 - d_o^2}{4d} \cdot \frac{1}{t_m}$$

A dimensionless quantity analogous to the Stanton number (commonly adopted to represent the heat-transfer performance of finned surfaces) is:

$$M = \frac{m}{v} = \frac{d^2 - d_o^2}{4d} \cdot \frac{1}{t_m} \cdot \frac{1}{v}$$

Technique of Investigation

A simple calculation showed that owing to the high flow rates, it was not practicable to determine mass transfer by measuring the increase in conductivity produced in the main stream by injecting electrolyte at the fin root. Consequently, the possibility was examined of using the fin space itself as an electrolytic cell and measuring the mean residence times associated with the radial flow from this cell. The general requirements were:

(a) The inclusion of an electrically insulating layer separating two parts of a finned tube, so that a potential difference could be applied between two successive fins;

(b) suitable methods of injecting electrolyte into the cell at a controlled rate, under various conditions of static pressure, and of causing instantaneous cut-off of this supply;

(c) isolation of a sector of the cell within which the variation in concentration would be small; and

(d) ensuring an initial electrolyte normality, N, of such magnitude that the solution in the fin-space would be essentially at infinite dilution. This would serve the dual purpose of allowing a true value of concentration to be ascertained by a simple measurement of current, and of simplifying the expression for the mass-transfer coefficient. At the same time, n should be as large as these conditions permit, so that the required sensitivity of measurement might lie within reasonable bounds.

These conditions were satisfied by cutting in half each finned tube to be investigated and joining the two sections by a Perspex insert, the dimensions being suitably selected to leave the original fin-spacing unaltered. This insert had a cylindrical bore in which was located a spring-loaded Perspex piston fitted with sealing rings (see Fig. 4). In the normal piston position the rings served to prevent transfer of fluid from the electrolyte supply to the main channel, and vice versa, through the injection hole which connected the inside of the finned tube to the "coolant" stream.

The electrolyte was supplied to the tube interior at a measured rate from a variable-pressure constant-head tank, thus enabling a check to be made on the normality within the fin-space after the determination of mean residence time. This gave an indication of the validity of the result, calculated as described above. It was necessary, of course, to perform a prior experiment to examine the current-concentration characteristics of the electrolyte and so establish a suitable value for the initial normality, N. In fact, the experiments were conducted using a normal solution ($N = 1$) of sodium nitrate. On applying pressure the piston could be depressed, so exposing the injection point; relief of the pressure would cause the spring to return the piston to its original position, cutting off the flow of solution almost instantaneously, since the diameter of the injection hole was only about 0.02 in. The friction opposing the piston movement was small and the spring stiffness low, so that injection could be effected at a pressure as close as desired to the static pressure in the fin-space, even at low values of Reynolds number.

The sector required for the measurement was insulated electrically from the rest of the fin by applying to the latter a thin layer of non-conducting varnish. It was symmetrically disposed with respect to the point of injection and its size chosen by examining the distribution of dye injected using the same technique.

The electrical measuring circuit is shown in Fig. 5. The voltage across a variable resistance (sensitivity control) in series with the electrolytic cell was recorded by a cathode-ray oscilloscope and camera. A variable-output transformer was used as a voltage supply since A.C. is useful for eliminating polarisation, and had the advantage of providing 50 cps "pulses" which gave an automatically recorded time-scale, to be preserved irrespective of the subsequent photographic enlargement and processing.

A single run consisted of setting the Reynolds number over the finned can in the main flow circuit, and then causing a constant flow of electrolyte to issue into the fin-space by application of a suitable pressure on the supply line. The procedure was to shut off the pressure by a manually-operated tap and record the change in concentration during the period of outflow from the sector. Fig. 6 shows a typical result recorded at a film speed of $\frac{1}{2}$ in./sec. and enlarged approximately 10 times. The mean residence time was assumed to be the time elapsing between the instant of shut-off and the point at which the concentration had fallen to half of its initial value. Build up of electrolyte in the closed-circuit system was negligible owing to the large capacity of the water reservoir.

Discussion

In other experimental work[7] residence times for a different type of system have been estimated using a pulse-injection technique. With the present arrangement, however, the control of the magnitude and duration of a suitable pulse and the measurement of its rate of efflux from the fin-space would have been extremely difficult to achieve. Nevertheless this technique has immediate advantages over the use of pulse injection for the present model. First, the flow of electrolyte is controlled by a simple compressed-air regulator, and is shut off by a manually-operated tap. Secondly, it is obvious that the ordinate of the curve (Fig. 6) representing fluid efflux from the fin-space has, at any time t after shut-off, been reduced by the amount $\int_o^t f(t)\,dt$, where $f(t)$ is the functional representation of what might be termed the "ideal" pulse. The latter term has been invoked because the conditions of the experiment inherently simulate the normal state of convection for the fin-space as a whole. Furthermore it may readily be demonstrated that the value of t given by $2\int_o^t f(t)\,dt = \int_o^\infty f(t)\,dt$, which is the value taken to represent mean residence time in the experimental work, is very nearly equal to t_m even if the function $f(t)$ is slightly askew. The oscilloscope records reveal, in fact, that the forms of $f(t)$ in question are reasonably symmetrical so that a fairly accurate value of mean residence time may be obtained immediately on inspecting the individual records and without a precise knowledge of $f(t)$. With a pulse technique graphical or numerical integration would normally be needed to determine t_m.

The heat-transfer performance of a surface may be represented by an equation of the form:

$$St \equiv F(\mathrm{Re}, \mathrm{Pr})$$

relating the Stanton, Reynolds and Prandtl numbers. For gases under reactor operating conditions, and also in this model, Pr is essentially constant and therefore

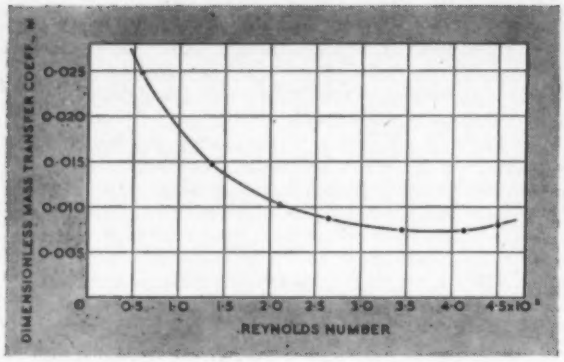

Fig. 7. Variation of dimensionless mass-transfer coefficient (M) *with Reynolds number for a tube with four fins per inch.*

need not be considered. Replacing St by its analogue M, it would be expected that the latter quantity would now be a function simply of the Reynolds number over the finned tube. Fig. 7 illustrates the variation of M with Reynolds number for a tube having four fins per inch and overall and root diameters of 2¼ in. and 1.3 in. respectively. In this instance Re was calculated from the formula

$$Re = \frac{v\,(D-d)}{\upsilon}$$

where D represents the internal diameter of the channel and υ the kinematic-viscosity of water at room temperature.

Conclusion

It appears that the technique developed affords a satisfactory means of estimating mass transfer from transversely-finned tubes of the type used in gas-cooled nuclear reactors. The use of probes, which would adversely affect the flow conditions, is completely obviated; the methods used are straightforward and the apparatus simple. In future research it is intended to measure the intensity of turbulence inside the fin-spaces by means of statistical analyses of the "steady-state" or equilibrium efflux patterns, and to attempt to establish the nature of the correlation between this quantity and mass transfer. There also exists the possibility of obtaining further information about the turbulent diffusion process operating, by analysing the functions $f(t)$ for different fin arrangements.

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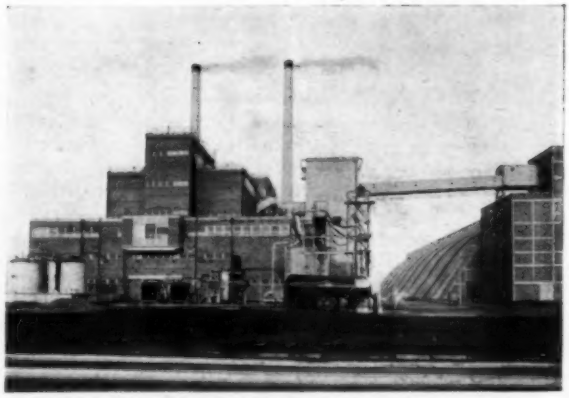
I.C.I.'s CCF Plant World's Biggest

SINCE the early 1920s I.C.I. have manufactured fertilisers at Billingham and today more than half of the Division's total output, now in excess of 1¼ million tons a year, is in this category. In September, 1958, I.C.I. brought into operation their Concentrated Complete Fertiliser (CCF) Plant, which they claim is one of the largest of its type in the world and in whose design they were assisted by Dorr-Oliver, who manufactured many important pieces of equipment installed in the new plant. Over the past three years, including the new CCF plant, I.C.I. have invested some £15 million in plants associated with fertiliser production.

In the CCF plant the solid raw materials—imported muriate of potash and Billingham sulphate of ammonia—are crushed, weighed and conveyed to a piece of equipment called a "blunger". Here they are mixed with mon-ammonium phosphate liquor which has been brought by special road tankers from the Phosphate Reaction Plant. Granulation begins in the "blunger" and is completed in a large rotary drier. From here the dried granules are screened, cooled and then conveyed to the silo.

For convenience of operation the plant is divided into two identical systems, the equipment being symmetrically arranged in the plant layout. The manufacture of mon-ammonium phosphate at Billingham early in 1930 made possible the production of the first granular CCF later that year. Different compound fertilisers were added to the selling range and the plant was extended in 1933. During the war, when production reached record levels, the range of CCFs was limited in the interests of higher output, and from 1946 only one was made. This contained 12% N, 12% P_2O_5, 15% K_2O, until in 1956 the potash content was increased to 18%.

CCF is packed and dispatched by road and rail from a new packing shed designed on modern lines and situated



I.C.I.'s new CCF Granulation Plant at Billingham. The storage silo (right) is shown at the rear of the plant.

near the CCF plant. The "make" can be conveyed either direct from the plant to the packing shed or via the air-conditioned silo from which the product is packed as required. In the packing shed, machines fill CCF into paper or jute sacks, the former being of either the stitched or valve packing variety. Loaded bags fall down chutes through the floor on to the loading platform below, where modern facilities for rail and road loading have been provided.

As a result of the detailed study of plant layout requirements prior to the design stage and the extensive use of instrument controls methods, I.C.I. state that the process is operated and maintained by a small labour force at a very high level of production.

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PROBLEMS IN ORGANISING CHEMICAL PLANT PROJECTS

An examination of the problems of organising complex large-scale projects projects and suggested methods of solving them

by M. DAVIDMANN, B.Sc.

LARGE process plants result from the joint work of many specialists. Difficulties have been experienced in obtaining effective teamwork and, as a result, the chemical plant contractor tends to organise his work into project teams. The project engineer, in charge of the team, is responsible for the project. Difficulties arise when a number of projects are being handled at the same time, particularly when the contractor is working at top capacity, quoting short delivery periods in a competitive market.

Organisation Charts

A company's effort consists of a variety of tasks. The larger company is arranged, according to size or task, into work units such as divisions, departments and groups. Responsibility is assigned to each work unit's manager for the work done by the unit he commands.

Organisation charts, a form of line diagram, depict work units in relation to each other. Titles of senior executives are given. Such charts indicate the arrangement of work units and the delegation of responsibility. They vary in scope and detail from those depicting the organisation of related companies to those showing the detailed organisation of a small work unit.

Part of an organisation chart for a chemical plant contractor is shown in Fig. 1. It is seen that its levels of position indicate the superior/subordinate relationship between individual executives. In general, an executive is responsible to his immediate superior for his own work and for that of his subordinates, and this is shown by the lines on the chart. Hence the organisation chart is used to illustrate: (a) the division of the company's task into work units; and (b) the executive chain of responsibility and command.

Activity Diagrams

Within an organisation there exists also, apart from the superior/subordinate relationships called "line" relationships, the constantly occurring activity between work units which is not shown by the organisation chart.

Intergroup activity is illustrated by an activity diagram, such as Fig. 2a, which illustrates the activity surrounding the purchasing function, that is the Buying Department, generally within the organisation defined by Fig. 1; outside suppliers are here regarded as a distinct work unit. Each separate area represents a work unit, common boundaries indicate activity between the work units on either side of the boundary, and the diagram also shows contacts related to purchasing, but between work units that exclude the Buying Department.

The system of activity of Fig. 1 is as follows: Technical, Works and Erection requisition purchases, which Buying arrange with outside suppliers. Erection contact Works to find out if requirements can be met from within the organisation, purchases being arranged through Buying. A similar situation exists between Technical and Works, but only seldom are Erection in contact with Technical on matters of purchasing. Buying is in direct contact with outside suppliers but Technical, and to a smaller extent Erection, are also in direct contact with outside suppliers. Buying are supported by Legal for contract clauses and keep Accounts informed on orders placed. All Works purchasing is negotiated through the Buying Department.

The main characteristics of this type of activity, which we will call Type "A", are apparent complexity, and consultation between work units which excludes the Buying Department.

Activity Between Groups

Type "A" activity surrounding a Buying Department is illustrated by Fig. 2a. Three separate departments are in contact with outside suppliers and this may lead to a threefold overlapping. This can create difficulties, as Buying Department may not be aware of contacts made with outside suppliers by other departments. In particular, difficulties can arise if company regulations call for a number of competitive bids each time a contract has to be placed. It is not clear which department decides how the order should be placed. Difficulties are particularly marked in large organisations facing complex tasks. Further, a considerable amount of consultation has to take place between other departments of which Buying Department has no knowledge, and there is the possibility of contradictory letters being sent to outside suppliers.

The activity around the Buying Department could be quite different, however, as departmental functions and interdepartmental practices vary from company to company. For example, the activity might be as illustrated by

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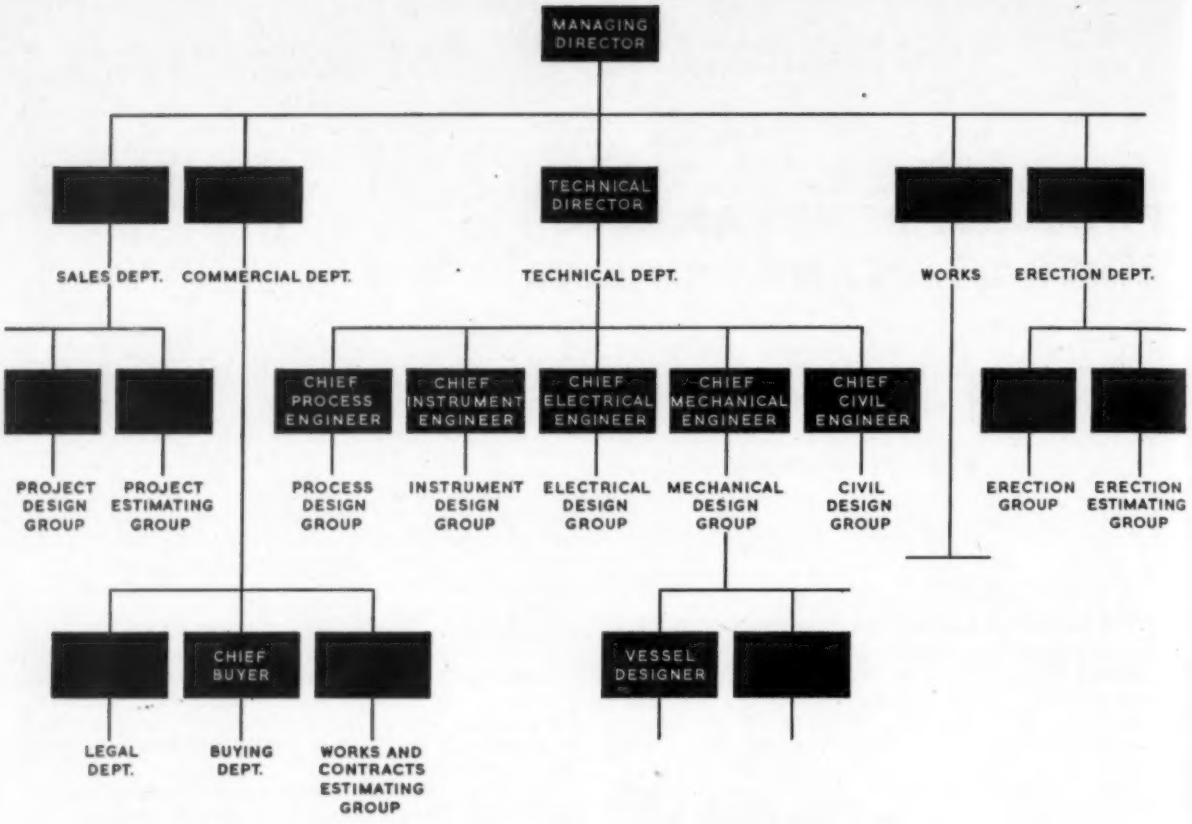

Fig. 1. *Organisation of a chemical plant contractor.*

activity diagram Fig. 2b, which we will designate Type "B". Here all contact with suppliers is through the Buying Department; contact between the various departments served by the Buying Department is discouraged. All inquiries are sent out by the Buying Department, including inquiries from Technical Department or Erection Department for supplies from Works. In consequence, Buying Department arrange technical discussions with outside suppliers.

On the surface, Type "B" activity seems a simpler arrangement of activity than Type "A" and thus seems more effective, as the Buying Department have full control over contact with outside suppliers and over internal contacts regarding supplies from Works. However, the Buying Department now acts as a forwarding agency and are concerned with matters not directly related to purchasing, and a large amount of interdepartmental correspondence is unavoidable. In one case, a large company had the ruling that letters to outside suppliers had to be signed by the Chief Buyer, in an effort to reduce the volume of internal correspondence resulting from Type "B" activity. Confusion exists as to who is responsible for what; for example, it is not clear whether the Chief Buyer is responsible for the letters he signs. Also, a considerable amount of time is now spent by Buying Department staff in arranging and taking part in technical discussions.

The method used here for illustrating and describing activity between work units can be applied equally well to analysing activity between a number of work units within one department, such as, for example, the design groups within a technical department which is responsible for designing a range of chemical process plants. We are considering here only design work on a plant for which the order has been received, but not contact with client or other departments, the organisation being that of Fig. 1. It should be remembered that a number of dissimilar plants are being dealt with at the same time.

Type "A" activity is illustrated by Fig. 3a. Process specify process requirements to all other groups. Mechanical specify their requirements to Instrument, Electrical and Civil. Electrical have to contact Instrument, Civil and Mechanical. Instrument have to contact Electrical for supplies. Civil take into account other groups' requirements. The activity diagram indicates the complex activity that makes up the design of just one process plant and there are thus opportunities for inefficiency and muddles. An effort can be made to keep all groups informed of each other's work, but generally this will fail. Considerable overlapping is likely and some work may not be done at all. Work done by one group can run contrary to the requirements of another.

Type "B" activity is illustrated by Fig. 3b. A new executive has been appointed to co-ordinate work of the design groups and once again this appears to be a more effective arrangement. Direct contact between the design groups is frowned upon and Project Group act as post office. The Project Engineer now assumes responsibility for design. As a number of plants are being designed at the same time, it is likely that a designer now has his responsibilities divided among his own immediate superior and two or more project engineers.

We can draw some conclusions by comparing the two

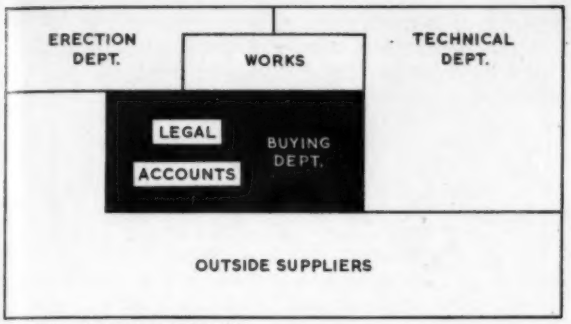

FIG. 2A.—ACTIVITY TYPE 'A'

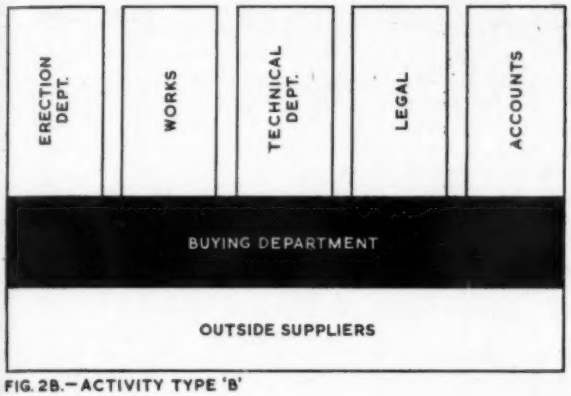

FIG. 2B.—ACTIVITY TYPE 'B'

Fig. 2. Activity diagrams for buying department.

types of intergroup activity based on the examples given. Type "A" is too complex to be shown on an organisation chart. Type "B" is much simpler; it is in fact no more than a type of organisation chart in which the lines which interconnect positions have been replaced by contact between boundaries. A chart for Type "B" activity which shows the relative positions of the groups concerned looks straightforward, but cannot be superimposed upon the chart for the entire organisation without confusing diagonal lines which indicate divided responsibility between executive chains of responsibility and command. In the Type "B" scheme one group co-ordinates the work of other groups.

The more complex Type "A" activity, unless clearly defined, results in inefficiency and difficulties. When an attempt is made to overcome the disadvantages by causing the work of some groups to be co-ordinated by one, Type "B" activity results. It is significant that an explicit organisation chart gives rise to Type "A" activity and that activity Type "B" corresponds to a confused organisation chart. In other words, when it is realised that intergroup activity is the cause of inefficiency, an attempt to overcome this is made by trying to fit a co-ordinating function across executive chains of command and responsibility. This generally makes the organisation more cumbersome, creating more paper work. Where two people worked together in Type "A" activity, there now stands between them the third, the co-ordinator. Responsibility and specialist activities are divided and the organisation has lost, rather than gained, efficiency in changing from Type "A" to Type "B" activity.

The following points arise in transition from "A" to "B":

(1) The organisation is a functional one; each division or unit corresponds to a function or service.
(2) Interdepartmental activity, being of Type "A", leads to individuals in different departments not working together as an efficient team.
(3) A solution is attempted along the lines of co-ordinating the work done by the various departments. Co-ordinators are appointed, not because "co-ordinating" is an essential part of the task the organisation is tackling, but because of internal defects in organisation.
(4) The co-ordinator relies on the co-operation of those whose work he co-ordinates. If they did not work in harmony before his arrival, they are scarcely likely to work well subsequently, especially since the position and work of the co-ordinator appear vague. Hence he has to be given authority so as to command co-operation. He cannot be given authority without responsibility and thus he is given responsibility for at least some functions.
(5) This immediately cuts across the functional division of the organisation, that is, across established chains of responsibility and command, bringing in its wake divided responsibility and going some way towards breaking up specialist departments. The organisation loses efficiency.
(6) To meet this situation the co-ordinator may be given still more responsibility, reducing efficiency further.

In the case of the chemical plant contractor, evidently the Project Engineer is the co-ordinator, and his function is the unreal one of "co-ordinating". In the end functional departments disappear altogether, and are replaced by teams, each being a small contracting organisation of its own. Each team at this stage is likely to repeat all the mistakes made already by other teams. Project teams take precedence over functional groups and specialists have difficulty in keeping abreast of their subject as know-how tends to be scattered in project files instead of being absorbed and correlated by the specialist's own group.

The appearance of a co-ordinator within an organisation signifies that functional departments do not work well together. His appointment makes the situation worse and is no solution. Hence one has to examine the explicit form of organisation chart together with its corresponding Type "A" intergroup activity, so as to isolate the defects. Once known, they may be treated and removed.

Line Relationships

One feature, the lines of Fig. 1, reveals that the Vessel Designer does not report to the Technical Director, either directly or through the Chief Process Engineer, as this would mean that he is by-passing his immediate superior, the Chief Mechanical Engineer. Such by-passing would mean that the Chief Mechanical Engineer could not effectively control the work done by his subordinates; and it would antagonise him. It would in due course upset the subordinate as well, as he would appear to be working for two superiors, with resultant uncertainty of position. In other words, by-passing upsets the organisation, the by-passed executive being unable effectively to carry out or have carried out the work for which he is responsible.

Extending this argument to positions on the same level, we can take the Chief Process Engineer, the Chief Mechanical Engineer and the Chief Instrument Engineer as examples. They report to their immediate executive superior, namely the Technical Director, only on matters for which they are responsible; for example, on work done by themselves or their subordinates. The Chief Process Engineer does not report to the Technical Director on work done by the Chief Instrument Engineer or on

work for which the latter is responsible, and the Chief Process Engineer should not be asked to do this. If the Technical Director were to ask the Chief Process Engineer to report on or to do work which falls within the limits of the Chief Instrument Engineer's area of responsibility and command, then two executives at the same level would, in effect, be responsible for similar and overlapping work, and immediate conflict between the two executives can result, to the detriment of work done by either one or the other or both. Divided responsibility would mean that two work units could be duplicating each other's work, that some work might not be done at all, since each work unit assumes that it is being done by the other, and it is possible that through lack of definition of responsibility neither will benefit from results obtained in the field.

In other words, the organisation chart depicts the executive chain of responsibility and command, and if this is by-passed, or if responsibility is divided so that one executive is responsible to two superiors, or if responsibility is divided so that two executives are responsible for overlapping work, trouble can be expected. However, it is worth while mentioning that some executives may be unwilling or incapable of accepting responsibility and that to them a system of divided responsibility appears to have advantages which in fact do not exist as far as the organisation's aim to carry out its work effectively is considered. At the same time, changes upset people and therefore they should be introduced gradually, with the agreement of those affected by them.

Functional Relationships

Activity between work units, however, consists of contact between individuals, and the relationships between executives in different work units are termed "functional" relationships. Neither organisation chart nor activity diagram illustrate or define functional relationships.

Functional relationships, however, have been clearly defined by JAQUES.[1] Of two executives in a functional relationship, one is the "responsible" executive, the other is the specialist, that is, the "prescribing" executive. Each executive is responsible to his own executive superior, and to no one else. The responsible executive assumes responsibility for obtaining specialist advice, which he can accept or reject, and for reporting useful results back to the specialist. The prescribing executive carries responsibility for giving specialist advice, that is for prescribing, and for the quality of his prescription.

This functional relationship is perhaps best illustrated by an example. The process designer is responsible to the Chief Process Engineer for satisfactory operation and performance of the process plant being designed. The instrument engineer is responsible to the Chief Instrument Engineer for his work, which consists of specifying the most suitable instrument types and suppliers, and of laying out and designing instrument panels. In this case, the process designer is the responsible executive, the instrument engineer is the prescribing executive, and the instrument engineer thus provides a specialist service for the process designer. The process designer would issue a general specification, listing instruments, operating conditions and ranges to the instrument engineer, with a request for detailed specifications. The instrument engineer submits his detailed specifications and drawings to the process designer, this being his prescription. His prescription could also be a recommendation for installing one type of instrument rather than another. The process designer is responsible to his immediate superior for accepting or rejecting the prescription; the instrument engineer is responsible to his own immediate superior for its quality.

Similarly, the respective responsibilities of process designer and buyer are immediately clear when it is realised that the process designer is the responsible executive, the buyer being the prescribing executive.

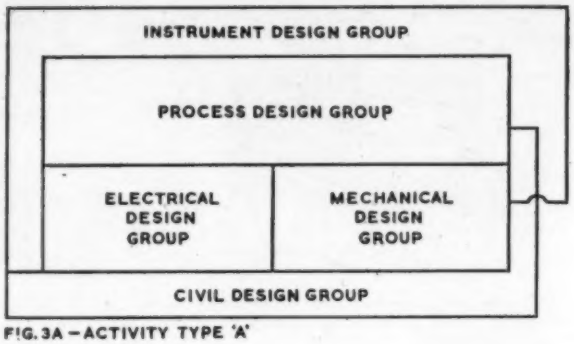

FIG. 3A – ACTIVITY TYPE 'A'

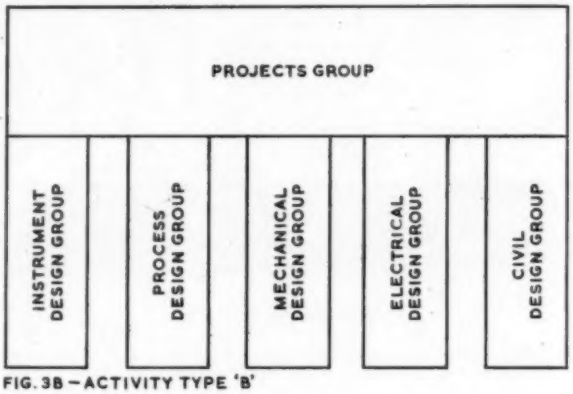

FIG. 3B – ACTIVITY TYPE 'B'

Fig. 3. Activity diagrams for design groups in technical department.

Functional Organisation

It follows that if an organisation is to be effective it has to be divided into functional work units. The task which the organisation faces thus has to be divided into parts, each of which corresponds to an activity which can be covered by one specialist department.

Fig. 1 illustrates this point by contrast. Three different groups are engaged in estimating, each one located in a different department. Also, design work is carried out by two departments: Technical Department designing for contracts, Sales Department designing for quotations. Responsibility cannot clearly be assigned, the disadvantages of divided responsibility having been mentioned already. Further, the splitting up of a specialist activity into separate parts, situated away from each other in the organisation, tends to prevent accumulated knowledge and experience from being utilised effectively. It is more likely than not that the experience gained by Technical Department during detailed design and commissioning would not effectively contribute to prequotation design by Sales Department.

Cases

OWEN and TURNER[2] have described an organisation for provision of major chemical plants. There is the "Engineering Branch" and the "Purchasing and Accounts Branch", but the Engineering Branch is responsible for cost control. Within the Engineering Branch there are

three departments or chains of responsibility. One of these contains such varied tasks as estimating, electrical design, instrument design, inspection and buying and presumably this is the result of an attempt to combine supporting groups in one department.

However, the service function of buying involves two departments within the Engineering Branch as well as the Purchasing and Accounts Branch. The design engineer in one department passes definition to a buying engineer in another department who, in turn, works through the appropriate contracts group in Purchasing and Accounts Branch who refer back not to the buying engineer, but to the design engineer who recommends acceptance of a particular tender, the placing of contracts being the responsibility of the Director of Accounts! The estimator in one department of the Engineering Branch prepares cost-estimates, but the project engineer in another department is responsible for the estimate.

This is not a functional organisation nor are functional relationships recognised. Nevertheless it makes the process engineer responsible for performance. Hence he has been given additional authority over other specialists such as mechanical engineers and draughtsmen and is consequently called "Project Engineer". We have seen, however, that such an attempt to improve functional relationships succeeds only in making the situation worse and this applies particularly in this case as mechanical engineers appear to be preferred to chemical engineers for "project engineering" appointments. It is not understood that the difference between one process plant and another lies in the process, that is, not in the pipes and shells but in what takes place inside them and how it takes place.

In this scheme the Project Engineer is not the only co-ordinator. A number of "Engineers" have made their appearance whose sole purpose appears to be that of co-ordinating, such as the Buying Engineer, the Planning Engineer, the Progress Engineer. The organisation described by OWEN and TURNER has thus proceeded a considerable way along the path from "A" to "B" activity.

CURWEN[3] has described a number of different project organisations of which he has experience. Unintentionally he illustrates how Type "B" activity arises from lack of understanding of functional relationships. His organisation Type 1 is to some extent functional. The divisions of concern here are Chemical Engineering under a Chief Chemical Engineer and General Engineering under a Chief Engineer. CURWEN cites these disadvantages:

(1) the chemical engineering division act as consultants only, during detailed design and construction, but take over again for commissioning;
(2) construction division have insufficient information in the early stages of the work;
(3) drawing office is responsible both to the (mechanical) engineer and the chemical engineer for various aspects of its work, the drawing office being located in the Engineering division; and
(4) the chemical engineer is responsible for estimating the cost of the project but has no direct control over expenditure (the estimating office, however, is located in the Engineering division).

Since "consulting" is such a vague activity, one cannot be quite sure why point 1 is a disadvantage. Disadvantages No. 3 and 4 illustrate that functional relationships need definition and the same seems to hold for disadvantage No. 2, although this is stated in too vague a form to allow detailed comment. CURWEN concludes that "the function of a project engineer is split" and that the disadvantages arise "largely from the lack of a project engineer". He is in effect saying that there is no co-ordination and that a co-ordinator is required. He has noted symptoms but ignored the causes which prevent effective teamwork and seeks to improve matters by appointing a co-ordinator.

CURWEN's Type 2 organisation is also divided into functional units, although the Chief Engineer is now responsible for all design work and for construction. For this organisation he lists the disadvantages as follows:

(1) too many staff responsible to the Chief Engineer;
(2) while one engineer is supervising a project throughout, he is not fully responsible for all aspects;
(3) designers and draughtsmen in the drawing office are responsible to the chief draughtsman for mechanical design and to the chief chemical engineer for chemical engineering aspects of design;
(4) they are also responsible for co-ordination of instrument, electrical and civil engineering sections;
(5) when construction starts, the project passes to another section, and the construction engineer is responsible to the chief construction engineer and to the chief chemical engineer; and
(6) the chemical engineer is in charge of commissioning.

Point 1 is a comparatively simple management problem. The remaining points are the outcome of misunderstood functional relationships. The symptoms are stated, but the causes are ignored, and the organisation fails to achieve teamwork.

CURWEN sees a completed project not as the result of teamwork but as the result of each specialist taking charge, in turn, of the project as a whole. To him there appears only one solution and that is to appoint a co-ordinator, that is the Project Engineer.

CURWEN's ideal organisation is his Type 3, and with this he has reached an advanced stage of Type "B" activity. Process Design, including brief specifications for instrument, electrical and civil engineering requirements, is completed and then the project engineer takes complete charge. He is responsible for mechanical design and testing, drawing office, erection, commissioning, timing, cost control, requisitioning of equipment, training operators and requisitioning spares. He also co-ordinates civil, electrical and instrument engineering, ordering, progressing of equipment, inspection and sub-contractors.

The functional division of the company's activity has virtually disappeared, as indicated by CURWEN's organisation chart for his Type 3 organisation. Specialists are responsible to project engineers and, presumably, to their group heads. This organisation suffers from all the disadvantages of Type "B" activity.

Co-ordination

The work undertaken by a chemical plant contracting organisation, and this includes the supporting administrative work (for example, that done by Personnel Department), can be divided into separate and distinct activities carried out in work units. Each work unit carries out an activity essential to the completion of the work, determined by the work undertaken.

The list of essential activities does not include "co-ordinating". There is no room in an efficient organisation for the co-ordinator, or liaison officer as he is sometimes called. He is unproductive, initials work done by someone else only to pass it on. In fact, he is the man "who has a vested interest in keeping two people apart who should be working together". This applies equally well to the co-ordinator who stands between an individual within the organisation and the customer or outside supplier.

The contemporary chemical plant contracting organisation contains a number of so-called engineers whose sole function appears to be co-ordinating. Examples are:

Project Engineer; Buying Engineer; Planning Engineer; Cost Control Engineer; Progress Engineer; and Expediting Engineer.

The project engineer serves as example. No one man can,

at our stage of specialisation, be directly and effectively responsible for all aspects of larger chemical plant projects. Project engineers are, in practice, given only part responsibility and their area of responsibility varies from contractor to contractor. It is because a project engineer's job is to co-ordinate that this variation in responsibility occurs, the apparent need for co-ordination varying from organisation to organisation.

It seems that the need for co-ordination reflects upon the individuals whose work has to be co-ordinated. To avoid stating this, and thus criticising individuals, co-ordinators are called "Engineers". This implies that they have some sort of engineering function and that some sort of engineering qualifications are required to enable them to co-ordinate. As a result, qualified engineers are doing non-productive work and the extent of this misuse of highly trained personnel is indicated by the larger chemical plant contractor employing perhaps up to 30 co-ordinators, which represent an annual salary bill of the order of £45,000. It is, of course, the responsibility of top management to ensure that line and functional responsibilities and relationships are clearly defined and understood. Hence the need for co-ordination reflects on top management and not those whose work may need co-ordinating.

Individuals in one group engaged in posting or signing letters written by individuals in another group are a clear example of a non-productive co-ordinating activity. When describing or defining functions or responsibilities, one should avoid the use of vague terms such as "co-ordinate", "collaborate" and "consult". They are a means of avoiding serious thought and of avoiding definition of functional relationships.

Resolving Difficulties in Functional Relationships — Cost Control and Timing

The chemical plant contractor has to control his costs so as to operate at a profit and to plan his work so as to hand over the proved plant on the promised day. The hypothetical example discussed in each case covers only a small fraction of the activity to be regulated for effective control. Only a part of the activity between Estimating, Accounting, Planning and one of the design groups of the Technical work unit is discussed. The examples illustrate how costs and timing can be controlled.

Control relies on functional division of work and for the purpose of this analysis it is assumed that a chemical plant contractor would divide his organisation into the following functional work units: Sales (Selling, Publicity), Technical (Development, Design, Drawing, Commissioning), Works (Manufacture, Inspection), Erection (Site Erection), Commercial (Estimating, Planning, Buying), Secretarial (Accounting, Legal, Office Administration) and Research.

Cost Control

Postulates: Estimating Department is responsible for estimating costs and therefore also responsible for the accuracy of the estimate, for comparing actual costs with estimated costs, and for correlating the results of such comparisons, so as to improve future estimates. Accounts Department is responsible for gathering data on actual costs and for quickly and accurately making these available in useful form. The design group is responsible for its own expenditure.

Requirements: Estimating Department require an estimate of design effort from the design group. They also require actual cost figures. Accounting Department require data for compiling actual costs. The design group requires to be kept informed on its expenditure.

Procedure: Estimating Department request an estimate of design effort from the design group, which supplies this. Estimating Department is "responsible", the design group is "prescribing". Estimating Department may accept or reject the design group's estimate. If Estimating Department include a smaller amount and a loss results, or if they increase the amount and the order is lost as a result of general over-estimating, they are responsible. Estimating Department are responsible to the Commercial Manager for the accuracy of the cost estimate and the design group is responsible to the Technical Manager for the quality of its own prescription. The order is placed and Estimating Department tell the design group the design cost included in the estimate. The design group regularly gives Accounts Department details of design effort made. Accounts Department convert this to £ s. d. and regularly report the moving total to the design group, which then has the necessary information to enable it to control its expenditure. At the end of the project, Accounts Department report the actual design cost to Estimating Department. Estimating Department now have the actual cost data they need for comparing with their estimate. Estimating Department report back to the design group their comparison between estimated and actual costs.

Timing

Postulates: Planning Group is responsible for estimating the completion date and therefore responsible for the accuracy of the estimate, for comparing actual completion dates with estimated dates, and for correlating the results of such comparisons, so as to improve future estimates. Design group is responsible for planning its own work.

Requirements: Planning Group have to be kept informed of work completed. Design requires to know time limits.

Procedure: At the pre-quotation stage, Planning Group would ask the design group to give an estimate of time required for design work. Planning Group are "responsible", the design group "prescribes". The design group gives the stages by which the work would be completed; for example, Process Design Group states final flowsheets available x weeks, and instruments specified y weeks, from starting work. On the basis of information such as this and on known or estimated delivery periods, the time required for completing the project is estimated. The order is placed and Planning Group issue to the design group the timing chart which indicates the time limits by which the various stages of design have to be completed, these being the limits on which the overall delivery period is based.

The design group, knowing both the cost and the time allowed, starts designing. It regularly informs Planning Group of work completed.

Planning Group regularly report back to the design group the comparison between estimated and actual completion dates. Note that the design group is "responsible". While Planning Group can indicate to the design group when increased effort seems to be required, the actual effort expended is the design group's responsibility.

Conclusions

Functional relationships are often not clearly defined and thus misinterpreted. This causes difficulties. It is usual for chemical plant contractors to appoint a co-ordinator in an attempt to eliminate the difficulties. The appointment of the co-ordinator only makes matters worse. There is no room in an efficient organisation for a co-ordinator. Three requirements have to be satisfied before an organisation can operate effectively: (a) the organisation has to be divided into functional work units; (b) line; and (c) functional relations have to be defined.

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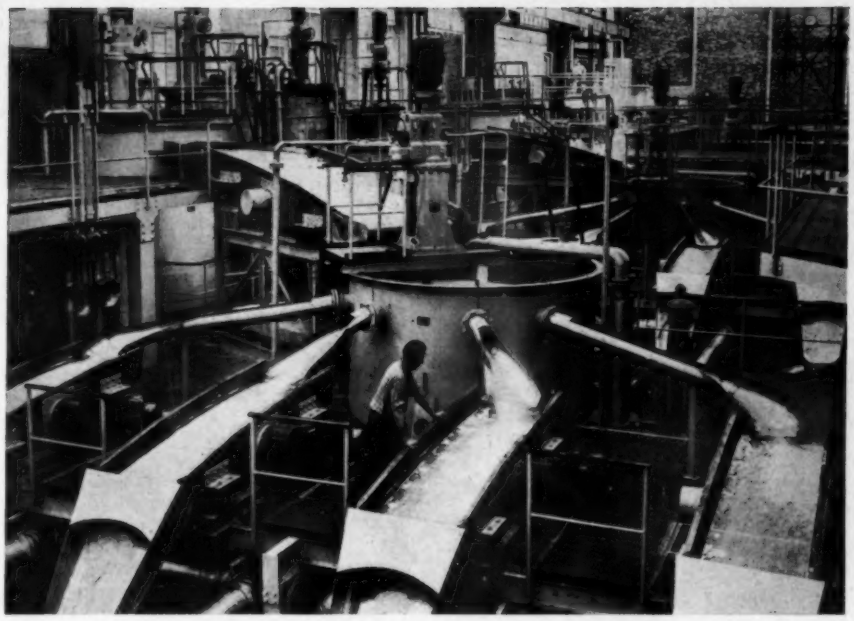

Fig. 1. Processing Buna cold rubber; part of dewatering plant. (Photo Bunabild.)

RAPID EXPANSION OF CHEMISCHE WERKE HÜLS

Synthetic rubber, general chemicals and raw materials for the plastics industries produced in a network of plants on one integrated site

AT Marl, in the famous Ruhr region of Germany, the Chemische Werke Hüls are now producing 600 different chemical products, of which the most important items are plastic raw materials. British journalists were recently shown around parts of the site of 2500 acres which has been rationally planned with a "grid-iron" of some 12½ miles of numbered roadways. There are also 25 miles of railway tracks laid in one direction, from east to west only, thus avoiding crossings. Almost in the centre of the works area is the old power station with an installed capacity of 204,000 kW, but there is also a new power station. All installations which use a great deal of steam, such as distillation plants, were erected south of the old power station. There are some 200 distillation towers in the works area. Among these towers the styrene column is particularly noteworthy, since it employs air-cooling for the distillate.

Turnover of the operating company has increased from DM 315 milion in 1953 to DM 523 million in 1957. There was a further increase in 1958, despite the general setback in economic development. Seventy per cent of the turnover is due to products which in 1950 were not yet being produced. About 5% of the value of turnover is invested in research every year.

The works employ a total of some 200 chemists and physicists, of whom more than half are engaged on research and development working from the Science Laboratory and Department for Application Techniques. There is also a polymerisation test installation equipped for a pilot production of up to 30 tons a month.

The most important product is polyvinyl chloride, which is being marketed under the name of Vestolit. Another major product is polystyrene (Vestyron). It is claimed that this summer Hüls is likely to become the biggest producer of styrene on the continent of Europe, with a capacity of 6000 tons per month, as a result of the expansion of production installations for monomer styrene. In addition, the firm is building a low-pressure polyethylene plant with a monthly capacity of 500 tons and is now beginning to offer polypropylene. Products also include auxiliaries for the manufacture of plastics such as plasticisers, solvents and synthetic resins, detergents and ethylene oxides with their derivatives, chlorinated hydrocarbons, organic acids and technical gases.

Producing and Using Acetylene

Acetylene is produced from gaseous hydrocarbons in an electric arc plant which is considered to be the "heart" of the works. Sources of the feed gas are waste gas from hydrogenation, coke-oven gas and natural gas brought from a well near the Dutch border. At present the plant consists of 17 arc furnace units, a number of which have been converted to automatic operation. The arc is struck inside a water-jacketed tube 3½ in. in diameter and 39 in. long. The average temperature in the tube is 1500°C, although regions at 18,000°C have been recorded. The feed

gas, mainly methane, is decomposed into acetylene and hydrogen, which is conveyed by long-distance pipelines to hydrogenation plants, fertiliser and detergent factories. Some carbon black is produced. This is now scrubbed out by a water-oil system.

The acetylene thus produced is reacted with hydrochloric acid to produce vinyl chloride which is polymerised in two different ways, yielding emulsion PVC and suspension PVC. From the emulsion process the PVC dispersion passes through conical spray driers. The dispersion is introduced from the top by compressed air and atomised through fine nozzles. A hot air current passes through the columns at the rate of 3½ million cu. ft per hr. The powder is passed through large filter plants and through a dust separator into its storage bin. In a granulating plant the PVC powder is mixed with stabilisers, dyes and, if necessary, plasticisers. This plant is controlled by an automatically-operated dosage equipment which can be adjusted for the required composition of the finished product, including the colouring, by means of a set of punched cards. To change the composition of the finished product it is only necessary to insert a different punched card.

The same plant also processes the low-pressure polyethylene (referred to below). In order to make the material suitable for cutting, the plasticised compound is sprayed with cooling water. The water is then separated in reciprocating troughs and cyclones.

In the acrylonitrile plant the production of hydrogen cyanide from methane and ammonia has been combined with that of acrylonitrile from acetylene and hydrogen cyanide; the entire plant is controlled from a single central control station. In addition, acetylene is used for reaction with chlorine to form tetrachlorethane which is then dissociated into trichlorethylene and hydrochloric acid. This plant is automatically controlled from a central station equipped with a graphic panel.

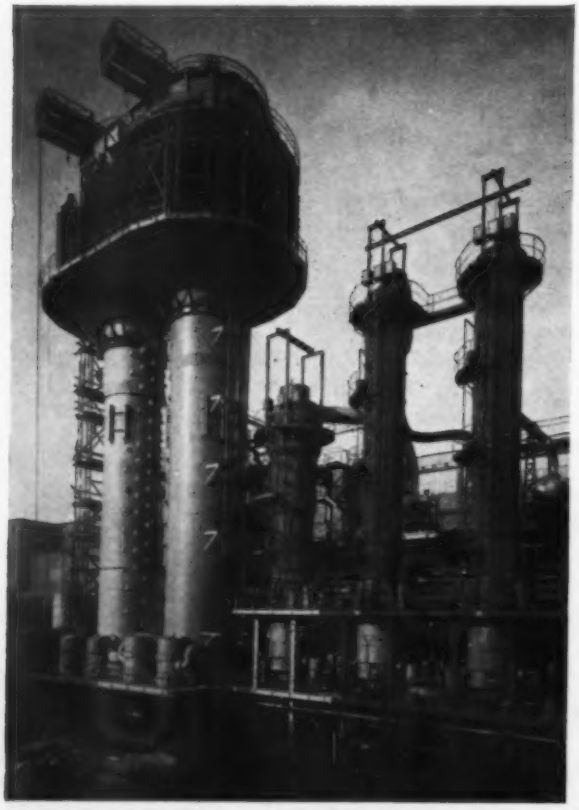

Fig. 2. Styrene distillation tower with air-cooling. (Photo by courtesy of Hulspress.)

Ethylene and Derivatives

Ethane and propane obtained from German refineries are decomposed to ethylene in a tube furnace or pipe still —again automatically controlled. The ethylene serves as raw material for the production of ethylene oxide and of styrene for the manufacture of polystyrene and polyethylene. Plant for the manufacture of ethylene oxide from ethylene and air by the contact process is the most modern automatically-controlled production plant at the works. The ethylene oxide is stored as a liquid cooled or under pressure.

Low-pressure polyethylene is being made by the Ziegler process in a plant with a monthly capacity of 500 tons. Tubes of this low-pressure polyethylene are said to have a wider field of application than those made of PVC. Polyethylene products with a weight of up to 22 lb. can now be made in one single process in the injection moulding machine. It is also suitable for making large containers for the transport of chemicals such as acetic acid, which are tough and suitable for sea transport. The material is called Vestolen A; polypropylene products are designated by the letter P.

Ethylene is used in the normal way for producing styrene via ethyl benzene. Hüls also make a copolymer called Vestoran, consisting of vinyl chloride and vinyl acetate as the raw material in the production of records.

Polyester Resins

Dicarboxylic acid esterified with glycols is used to make a polyester. Monomer styrene is added and the polyester resin results in a liquid form, and can then be hardened to the required degree by the addition of other chemicals. In the form of shapes or moulds reinforced by glass fibres, the resin processed in this way often surpasses steel in strength. Large containers made of this glass-fibre-reinforced polyester resin are reported as outstanding for their low weight and chemical stability.

Synthetic Rubber Plant

Normal butane from large refineries of Esso, BP and Gelsenberg Benzin A.G. is catalytically dehydrogenated by the Houdry process. It is heated to a temperature of 1100°F and passes into six reactors about 19 ft in diameter and approximately 45 ft long. Butylene and coke are formed, in addition to butadiene; the coke is deposited on the catalyst. These conversions are highly endothermic. Heat is supplied by superheating the catalyst bed in an alternating cycle by hot air; the gas containing n-butane is then fed to the catalyst bed for conversion and the excess heat is utilised for the dehydrogenation reaction.

Only about 12% of the product from dehydrogenation is butadiene; the balance is butylene, butane and a certain amount of C_4-hydrocarbonisomers. Butadiene is selectively removed. Butadiene and styrene are then copolymerised continuously in two polymerisation batteries of 10 agitators.

Laboratories and Experimental Production

A modern eleven-storey building is occupied by well-equipped laboratories. Plastic raw materials are test-processed at Hüls in a Department for Application Techniques which consists of a number of miniature factories around a central shed with a floor space of 16,000 sq. ft. Here processing conditions are investigated on production machines. About half the company's chemists and physicists are distributed throughout other divisions than the laboratories or the applications department; they also work on shop floor developments.

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A NOVEL APPLICATION FOR GRAPHITE HEAT EXCHANGERS

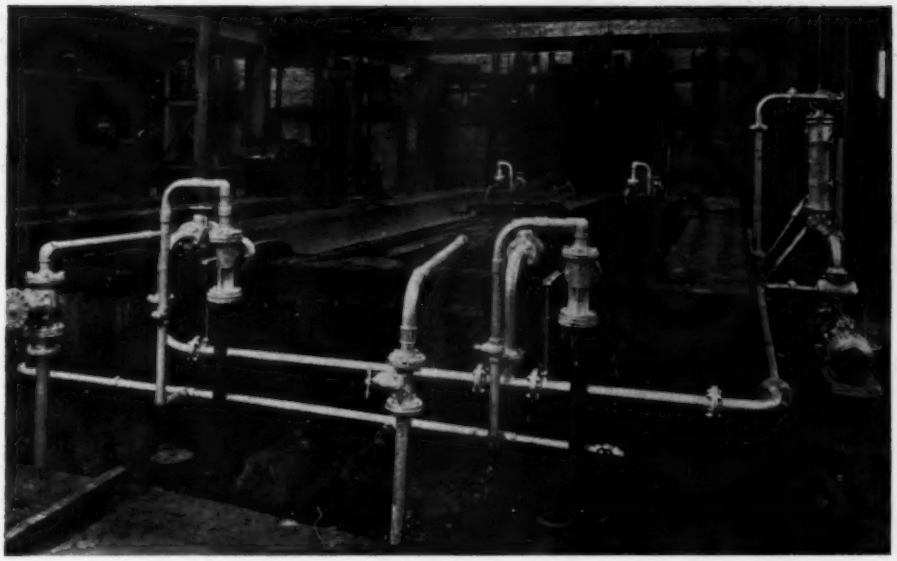

Fig. 1. A view of the graphite heat exchanger installation.

A recent design of exchanger brings about useful economies in a steel pickling plant

by **B. A. GARMAN, A. HILLIARD and N. H. RICHES**

THIS article outlines some of the experiences gained with the use of the Polybloc graphite heat exchanger[1–6, 10, 11] for the heating of steel pickling liquor. The application to be described refers to an installation in the bright drawn steel department of The Steel Nut & Joseph Hampton Ltd., Wednesbury: a noteworthy feature of this application is the economy it effects in a number of directions.

Pickling Plant

This comprises two pairs of boshes for steel bars and one pair of boshes for steel coiled bars or rods. Each pair of boshes may be considered as a unit; therefore, there are three units, each containing approximately 1200 gal. of about 11% H_2SO_4 pickling liquor. When the pickling liquor reaches an iron sulphate concentration of about 10%, it is returned to the acid recovery plant for removal of the iron sulphate. The reclaimed acid is then pumped back to the pickling boshes and is made up to about 11% H_2SO_4 concentration for re-use. Make-up acid is added to the liquor in the boshes when required.

Mr. Garman *is joint managing director, The Steel Nut & Joseph Hampton Ltd.* **Mr. Hilliard** *is Technical Adviser, Société Le Carbone-Lorraine.* **Mr. Riches** *is a Mechanical Engineer, Robert Jenkins & Co. Ltd., Rotherham.*

Previous Method of Heating

Originally this consisted of injecting live steam which, although producing the required working temperature, was wasteful. Moreover, this form of heating presented the serious problem of liquid build-up in the boshes due to excessive accumulation of condensate. Furthermore, it had the disadvantage in that it necessitated the periodical sending to waste of excess liquor, the disposal of which was somewhat difficult.

To avoid this problem, lead-covered steel coils were installed in the boshes. This involved a certain compromise between the size of coils necessary to heat the liquor and the space which the coils occupied being lost to useful production. However, it was found that this method of heating introduced several other disadvantages. The principal of these was the vulnerability of the lead-covered coils to damage by the charge of steel bars, and the resultant heavy cost of repairs. Pickling was slow because of lack of turbulence in the boshes, while iron sulphate scale tended to build-up on the coils. The additional resistance to heat transfer caused by the scale increased so rapidly that a point was reached when the coils could no longer cope with the required heating duty. This necessitated periodical boosting with live steam, which, in its turn, again introduced the problem of excessive build-up of liquor.

Alternative Methods of Heating

Alternative methods of heating, including the use of external heat exchangers, were therefore examined. Units constructed from graphite were considered particularly interesting because of the combination of excellent thermal conductivity with highly versatile resistance to chemical attack which characterises this material.

Various types of graphite heat exchanger were considered. The conventional tubular graphite units, for example, were thought to be too fragile for use in a steelworks. Monoblock units of the type described by Stancliffe[7, 8] and others[9] appeared robust enough, but their use was not favoured because of the multiplicity of resinous cemented joints used in their construction.

The news that the Polybloc type of graphite heat exchanger had proved remarkably successful for similar applications in a number of major continental steelworks led to further inquiries being made; these revealed that the first Polyblocs had been installed in steelworks since the early days of 1953 and had proved so satisfactory that, by 1956, they had been widely adopted by the European steel industry for the heating of pickling liquor. Indeed, evidence that this was an eminently suitable choice of exchanger for pickle liquor heating was readily forthcoming from a number of strip mills where the liquor in the continuous pickling plant was heated solely by Polyblocs. This led to the installation of the first graphite heat exchanger at one pair of the bar boshes at Wednesbury. The dimensions of the heat exchanger—it was only 9¼ in. in diameter and 32 in. high—seemed surprisingly small for a unit to cope with the required duty. Nevertheless, in practice its capacity proved completely adequate.

Polybloc Plant at Wednesbury

Each of the three pairs of pickling boshes is served by a small model of six blocks, with 6½ sq. ft of heat exchange area. The general layout is shown in the flow diagram (Fig. 2).

Pickling liquor is circulated through the exchangers at a rate of 1200 gal. per hr. Saturated steam at 20 psig (258°F) is supplied from a boiler which is exclusively used for this purpose. The fact that with the Polyblocs only one boiler is required, whereas two boilers were needed with the previous method of heating, is indicative of the efficiency and economy of these units. The plant deals conveniently with the pickling requirements, which is normally 50 tons of bars and 15 tons of coils per eight-hour day. However, this is by no means the limit of the capacity of these heaters.

It has been found that a convenient method of working is to keep the pickling liquor circulating through the exchanger continuously during the close-down period, and to arrange for the boiler to fire 25 min. and rest 35 min. in each hour. Continuous firing of the boiler is recommenced about ¾-1 hr before pickling is resumed. By this means, the temperature, which drops to about 120°F during the night, is up to working temperature of 140°F at starting time, a condition rarely achieved when heating by previous methods.

In order to prevent the formation of sulphate scale in the heat-exchange passages during a long shut-down, the steam is turned off and the pickling liquor is drained from the exchangers, which are then flushed with water.

The scale-inhibiting effect of the turbulent fluid flow through the exchanger, which is induced by the very short ratio of the length of the passages with respect to their diameter, has proved a great and very real advantage when handling fluids carrying salts and other precipitates, e.g., iron sulphate. That the passages of the Polyblocs are free from scale after almost one year of operation is evident from the fact that they are still performing at the original heat exchange coefficient of approximately 400 Btu/hr °F sq. ft (1950 Kcals/hr °C m²).

Installing the Polyblocs higher than the boshes facilitates draining, as can be seen from Fig. 1 (p. 411). Considerable latitude can be allowed in their siting to fit in conveniently with the general layout of the pickling shop, and they can, if desired, be situated at some distance from the actual boshes. In the installation described, the total floor space occupied is only 2 ft long by 6 ft, most of which is taken up by the pump. Experience so far indicates that if the very simple precautions, as outlined above, are observed, these exchangers can be expected to last indefinitely and they require practically no maintenance.

Economics

In a plant such as the one described it is difficult to arrive at strict comparisons. Because of the intermittent nature of the pickling process employed, the boshes cannot be covered and working conditions are therefore strongly subject to atmospheric changes. However, even if one considers only those aspects for which quantitative data are available, the savings which were achieved with the Polyblocs are quite impressive. Prior to their installation, the fuel consumption of the two boilers (which served the pickling shop exclusively) was about 15 tons of coal per week. This has been reduced to approximately 10 tons of coal per week. Taking the price of coal as £5 1s. 5d.

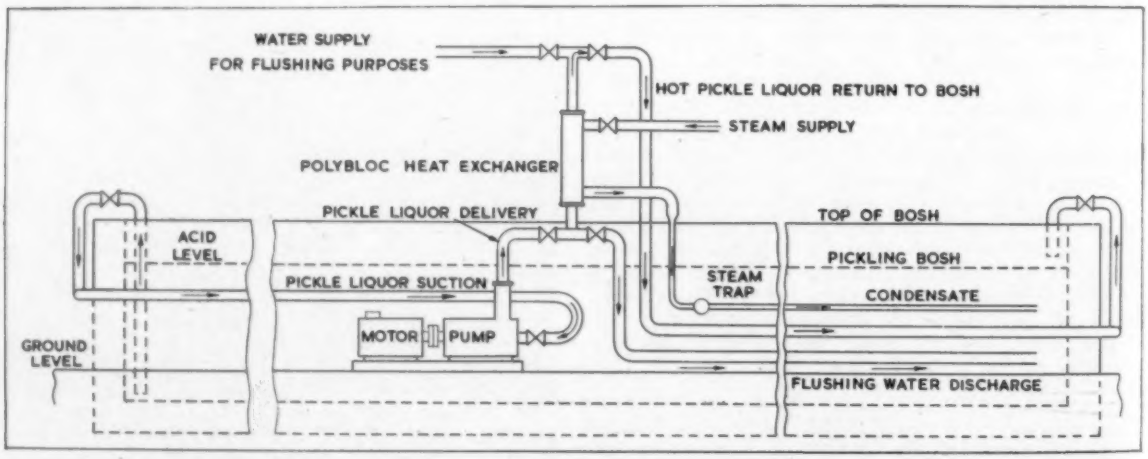

Fig. 2. Flow diagram of the pickle liquor heating plant using the graphite heat exchanger.

per ton, the saving of fuel amounts to over £1000 in a year.

The cost of repairing the coils—more than £800 per year—has been completely eliminated. In addition to the savings in maintenance cost, it has also been possible to make a reduction in the number of operators required, as without the heating coils each bosh holds more steel and the bundles can be removed from the baths more quickly since the care needed to prevent damage to the coils is no longer involved.

The plant can be brought up rapidly to efficient working temperature even in the coldest winter weather, and the efficiency of the graphite exchangers becomes evident under increasingly strenuous working conditions.

Satisfactory pickling is obtained with uniform regularity and there is now no build-up in the liquor levels. Whereas all these features represent very real savings, it is difficult to present them in an exact quantitative form. However, it is interesting to note that the first two mentioned savings alone amount to more than the price of the installation, including three Polyblocs with pumps and piping.

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Condensation of Mixtures of Vapours of Immiscible Liquids

THE inadequacies of previously published theoretical and experimental work on heat transfer during the condensation of mixtures of vapours of immiscible liquids have been discussed by STEPANEK and STANDART in a recent paper.[1]

For the condensation of a pure component, NUSSELT showed theoretically the dependence of the coefficient of heat transfer on the physical properties of the system. Since NUSSELT, many workers have investigated condensing heat transfer and have verified this dependence.

In the case of condensation of a vapour mixture of immiscible liquids this was investigated more recently by KIRKBRIDE[3] and others. In much of the later work the investigators have been content to use variants of the NUSSELT relation for the condensation of a single component without investigating mechanism of flow of the two-phase condensate in detail: in some cases it has been assumed that the composition of the condensate varied over wider limits. This is in conflict with the phase rule which states that at a given pressure it is possible to have only one temperature and only one set of liquid compositions corresponding to equilibrium in the vapour phase. During equilibrium condensation the composition of a mixture condensate should be exactly the same as that of the condensing vapours.

The authors make use of two idealised models of the heat-transfer process in order to derive an expression for the film coefficient of heat transfer when a two-phase condensate is formed. It was found advantageous to use two models to represent the actual process, one for the thermal régime and the second to describe the hydrodynamic régime. For the thermal régime the model chosen was based upon the following assumptions:

(1) The only resistance to heat transfer is in the liquid phase. Any temperature drop and diffusion effects in the vapour are neglected, has equilibrium condensation holds; (2) the liquid which better wets the metal (the organic liquid in the systems water-organic substance) condenses in the form of a film. The second liquid condenses dropwise upon this film; (3) the average behaviour of the droplets can be expressed by a model in which equal-sized droplets are distributed uniformly; (4) the shape of a droplet can be represented by a small cylinder of diameter equal to the maximum diameter of the drop and whose volume is the same as that of the drop.

For the hydrodynamic régime it was assumed: (1) that the action of the water droplets on the organic film is the same as the action of a water film of equivalent thickness; (2) the water film moves with a constant velocity the same as that of the surface of the organic film. As a result, a correlation was deducted for the film coefficient

To test the validity of the equation derived a series of experiments was carried out on the systems benzene-water, toluene-water, chlorobenzene-water and dichloroethane-water. One aim of the experiments was to determine the dependence of the coefficient of heat transfer on the temperature drop. In the case of a pure substance, h_c is inversely proportional to $(\triangle t)^{\frac{1}{4}}$. For the condensation of pure vapours the product of the coefficient and $(\triangle t)^{\frac{1}{4}}$ should be constant if the changes of physical properties resulting from a change of the average temperature of the film can be ignored; during the condensation of a mixture of vapours this quantity can depend upon the temperature drop. In investigating this dependence, the authors neglected changes in physical properties since the average temperature of the film at most changed by 4°C only.

Symbols Used

a = weight fraction of organic substance (kg/kg);
d = diameter of the tube (m);
R = heat of vaporisation of the mixture per unit weight of organic liquid (kcal/kg);
$\triangle t$ = temperature difference of vapour and wall of tube (°C);
h_c = film coefficient of heat transfer (kcal/m² hr °C);
γ = specific weight (kg/m³);
λ = thermal conductivity (kcal/m hr °C);
μ = viscosity of the organic liquid (kg hr/m²);
σ = surface tension (kg/m); and
$\triangle\sigma$ = difference of surface tensions (kg/m)

Subscripts

$_1$ = water; and
$_2$ = organic liquid.

The NUSSELT[2] relation for the condensation of a single constituent is shown to be valid for the condensation of two immiscible liquids if two correction terms are introduced. These terms were expressed by semi-empirical dimensionless quantities; thus the film coefficient is given by:

$$h_c = 0.725 \left[\frac{R\lambda_2^3\gamma_2^2}{\mu\,\Delta t d}\right]^{\frac{1}{4}} k_1(1+k_2\,\Delta t),$$

where

$$k_1 = \left[1-4.38\left(\frac{1-a}{a}\right)^{0.033}\cdot\left(\frac{\gamma_2}{\gamma_1}\right)^{0.62}\cdot\left(\frac{\Delta\sigma}{\sigma_1}\right)^{3.67}\right]^{\frac{1}{4}},$$

$$k_2 = 0.0584\left(\frac{a}{1-a}\right)\cdot\left(\frac{\lambda_2}{\lambda_1}\right)^{0.5}\cdot\left(\frac{\gamma_1}{\gamma_2}\right)^{1.4}\cdot\left(\frac{\Delta\sigma}{\sigma_1}\right)^{1.6}.$$

This equation satisfies the experimental results with an accuracy of about 7%.

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THE CALCULATION OF TERMINAL VELOCITIES

A comparison of two recently-published methods for rapid calculation of this important characteristic

by J. BERÁNEK and D. SOKOL

THE method for calculating the rate of fall of particles in fluids by RENÉ JOTTRAND has been published[1] and is faster than proceeding stepwise or using analytical expressions representing the experimental curves in a given region. We believe, however, that there is a faster and more exact method using a correlation[2] covering a very wide range of Reynolds numbers.

A general relation describing terminal falling velocity has the following form:

$$f(\mathrm{Ar}, \Omega) = 0$$

This relation is represented by Fig. 1, reprinted from BERÁNEK'S article,[2] and includes spherical particles and other particle shapes as cubes, tetrahedrons, octahedrons and cube-octahedrons. Most crushed materials have similar dynamic properties to these of tetrahedron particles, so in approximate calculations one can use the correlation corresponding to tetrahedrons.

The use of Fig. 1 will be demonstrated by means of three examples, comprising two parts: (1) calculation of Archimedes number, Ar; and (2) determination of Ω from Fig. 1, and calculating the terminal velocity of the particle, the only variable in Ω.

Conversely, the particle size of known terminal velocity and shape may be determined. Calculations can be made in any system of units; below the technical metric system is used (Kg force, m/sec.).

Examples

JOTTRAND'S two examples are taken for purposes of illustration and a new one is discussed.

Example 1

Calculate the velocity of fall of a particle of density $\rho_z = 2600$ Kg/m³ of effective diameter $d_z = 363$ microns in water at 20°C ($\nu = 10^{-6}$ m²/sec, $\rho_z/\rho_f = 1.6$):

Archimedes number corresponding to the spherical particle

$$\mathrm{Ar}_o = Z_z/\rho_f \nu^2 = \pi d_z^3\, g\, \rho_z/6\rho_f \nu^2$$
$$= \pi \times (3.63 \times 10^{-4})^3 \times 9.81 \times 1.6/6 \times 10^{-12} = 391$$

From Fig. 1, the corresponding value of $\Omega_o = 7.95$ then

$$v_{go} = \sqrt[3]{\Omega g \nu \rho_z/\rho_f} = \sqrt[3]{7.95 \times 9.81 \times 10^{-6} \times 1.6}$$

whence $v_{go} = 4.98$ cm/sec., or 0.152 ft/sec.

JOTTRAND'S method gives 5.5 cm/sec.

In case of irregular particles equal in weight to the above spherical particles, the criterion $\Omega = 5.6$ ($\mathrm{Ar}_o = \mathrm{Ar}$),

$$v_g/v_{go} = \sqrt[3]{\Omega/\Omega_o} = \sqrt[3]{5.6/7.6} = 0.902$$
$$v_g = 0.902 \times 4.98 = 4.45 \text{ cm/sec.}$$

Symbols Used

$\mathrm{Ar} = Z_z/\rho_f \nu^2$ = Archimedes number;
d_z = particle diameter;
g = acceleration of gravity;
v_g = terminal velocity;
Z; Z_z = apparent weight of particle;
ν = kinematic viscosity;
$\rho_z = \rho_z - \rho_f$;
ρ_f; ρ_z = denstiy of fluid and solid respectively;
$\Omega = v_g^3\, \rho_f/g\nu\rho_z$, dimensionless group; and
o = subscript for spherical particles.

Example 2

It is required to calculate effective diameter of carbon particles of density 1.4 if their terminal velocity in air at 500°C is 0.01 ft/sec. or 0.3048 cm/sec. ($\nu = 7.55 \times 10^{-5}$ m²/sec., $\rho_z/\rho_f = 3060$):

Assuming spherical particles, the criterion has the value:

$$\Omega_o = v_g^3\, \rho_f/\rho_z\, g\nu =$$
$$(3.048 \times 10^{-3})^3\, 3060 \times 9.81 \times 7.55 \times 10^{-5} = 1.25 \times 10^{-6}$$

From Fig. 1, the corresponding value of $\mathrm{Ar}_o = 6.3 \times 10^{-3}$ and the diameter of the sphere is then:

$$d_z = \sqrt[3]{6\,\mathrm{Ar}_o \nu^2 \rho_f/\rho_z \pi g} =$$
$$\sqrt[3]{6 \times 6.3 \times 10^{-3} \times (7.55 \times 10^{-5})^2/3060 \times \pi \times 9.81}$$
$$= 1.34 \times 10^{-5} \text{ m},$$
$$d_z = 13.4 \text{ microns}$$

JOTTRAND'S method gives 11.7 microns. It can be seen that there is close agreement between the two methods, although JOTTRAND'S method is based on the theoretical Stokes law in the viscous region and gives higher values of the falling velocity than the experimental results. This is the reason for JOTTRAND'S lower value for the calculated particle diameter in Example 2.

In the transition and turbulent region, the falling velocities of a spherical and irregular particle deviate appreciably. This is reflected in the next example, which also shows the simple calculation for the falling velocity of irregular particles. The exactness of the new method, which characterises the particle by its weight, cannot be attained in case of irregular particles by any method which defines the size of the particle by a linear dimension.

Example 3

Calculate the velocity of fall of uniformly sized particles of crushed alumina in water. Apparent weight of 100 par-

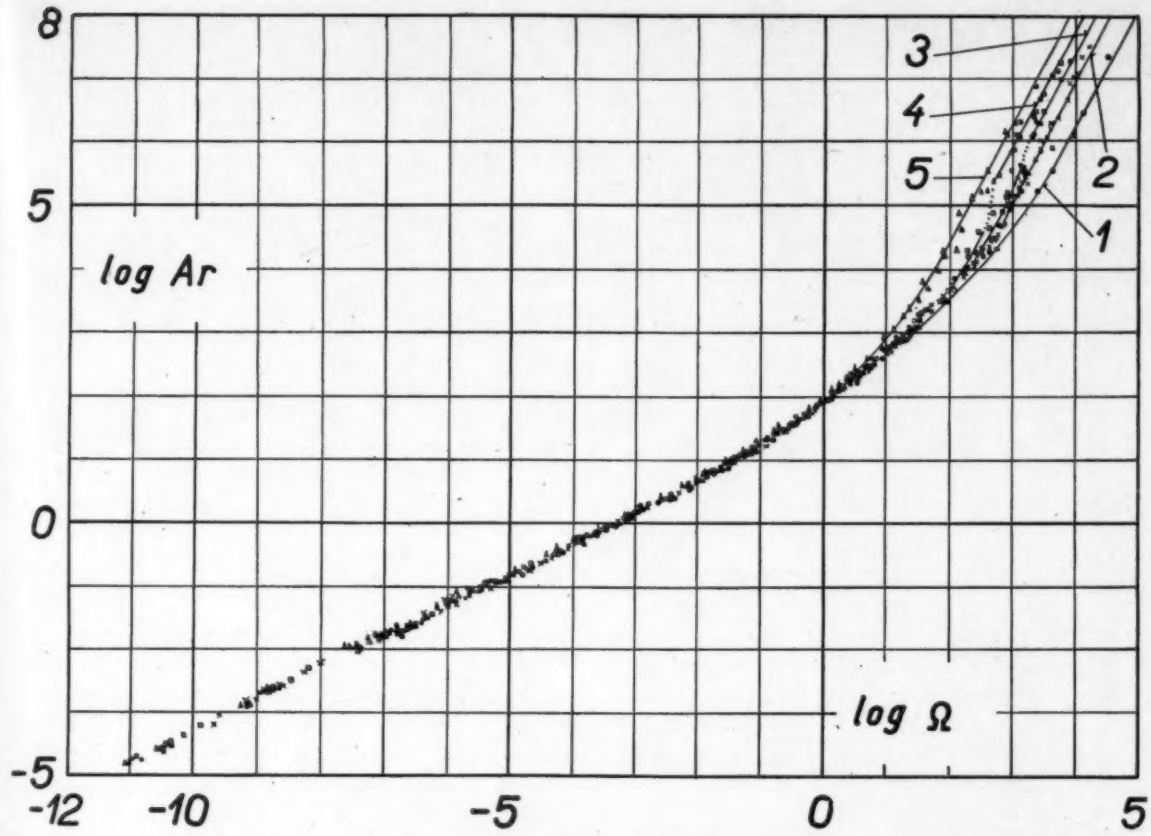

Fig. 1. Terminal velocities of different shapes of particles in fluids: (1) spheres; (2) cube-octahedrons; (3) octahedrons; (4) cubes; (5) tetrahedrons.

ticles in air $Z = 13.52$ mg. Specific gravity of crushed alumina $\rho_s = 254.8$ Kg/sec.^{2}/m^4 respectively of water $\rho_f = 101.1$ Kg sec.^{2}/m^4. Apparent weight of a single particle in air:

$$Z_{sa} = 13.52/100 = 0.1352 \text{ mg} = 1.352 \times 10^{-7} \text{ Kg}.$$

Apparent weight of the particle in water follows from: $Z_{sw} = Z_{sa}\ \rho_{sw}/\rho_{sa} = 1.352 \times 10^{-7} \times (254.8 - 101.1)/254.8 = 8.12 \times 10^{-8}$ Kg. Archimedes number is then:

$$\text{Ar} = 8.12 \times 10^{-8}/101.1 \times (6.59 \times 10^{-7})^2 = 1.85 \times 10^3$$

From Fig. 1 the criterion Ω corresponding to tetrahedrons is equal to 23 and the calculated terminal velocity:

$$v_g = \sqrt[3]{23 \times 9.81 \times 6.59 \times 10^{-7} \times (285.4 - 101.1)/101.1} = 0.062 \text{ m/sec.}$$

Supposing spherical shape of the crushed alumina, the corresponding criterion $\Omega_o = 59.5$ and

$$v_{go}/v_g = \sqrt[3]{\Omega_o/\Omega} = \sqrt[3]{59.5/23} = 1.37.$$

The velocity ratio v_{go}/v_g increases to 2.2 in the turbulent region in case of tetrahedrons and of most crushed materials.

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Sonic Conveying System

HENRY SIMON LTD., of Stockport, have released details of a new system of pneumatic conveying, the Simon Sonic Conveying System, claimed to be far superior to present conventional methods. Hitherto, it has been necessary to provide a separate compressor for each blowing line where materials are conveyed pneumatically between different parts of a plant. Air in such systems tends to take the path of least resistance, and lines heavily loaded are usually by-passed or become blocked.

Simon scientists have now developed a valve which, when installed in a blowing line, will keep the resistance of the line constant irrespective of the load. Any system using such valves will permit any number of lines to be powered from one compressor without any interaction.

The valve, which is simple, reliable and automatic, consists of a convergent-divergent nozzle so proportioned that the air passing through it reaches the velocity of sound. When the valve is interposed between a loaded line and the compressor, a pressure wave travelling towards the compressor as a result of a load change is halted at the valve throat, since the wave velocity of propagation is exactly equal to the opposing air velocity.

By careful selection of the profile of the valve nozzle and special attention to the surface finish during manufacture, Simon scientists have reduced any high pressure loss present to negligible proportions. Furthermore, they state that this loss is generally more than compensated by the gain in efficiency achieved by using compressors unsuitable for single blowing lines of the conventional type. The system is therefore reported to be inherently more stable and versatile than those in which each line is powered by its own compressor. The valve, which is of aluminium, is so designed that the flow can be preset to any value, and held as such regardless of load changes.

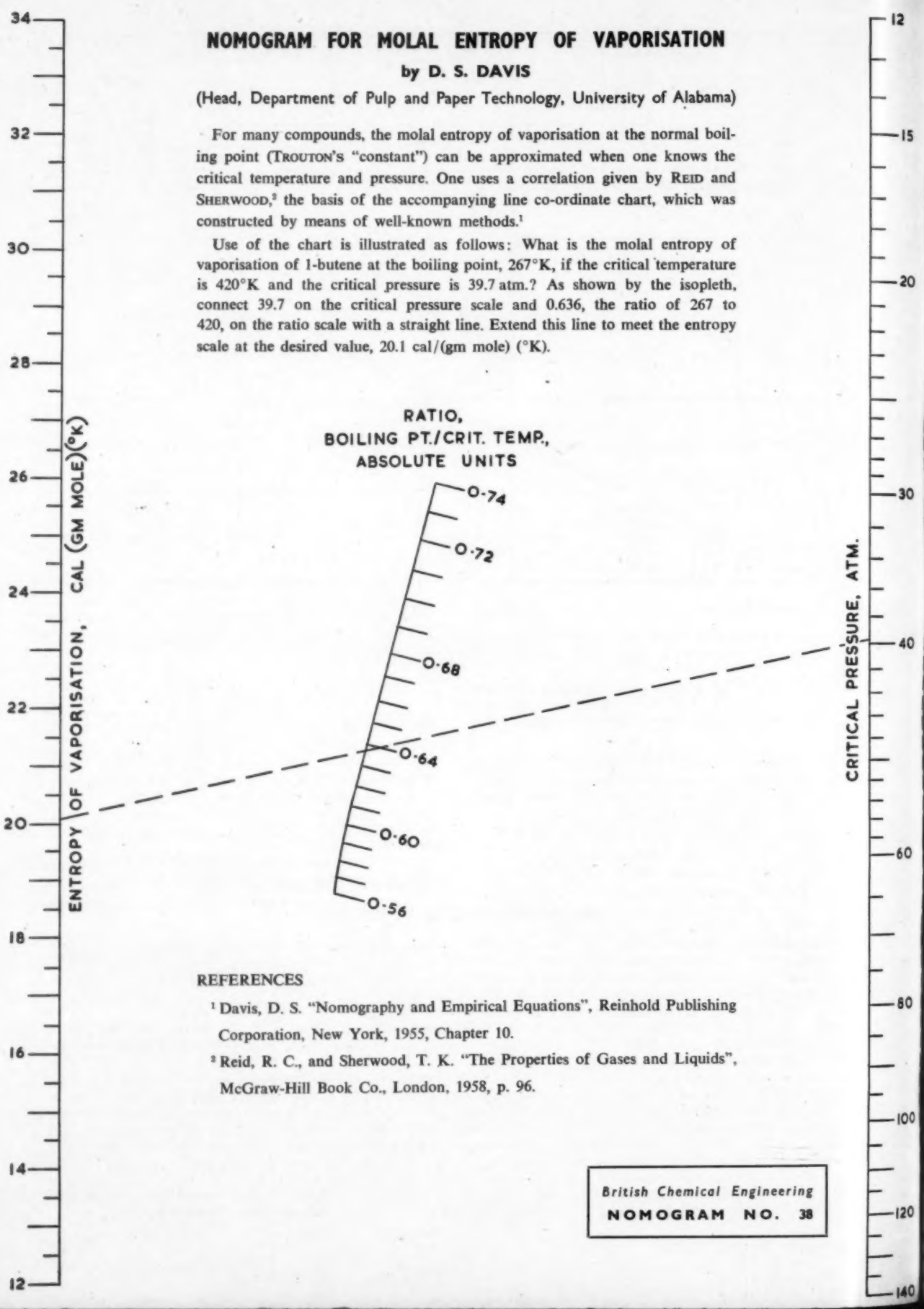
NOMOGRAM FOR MOLAL ENTROPY OF VAPORISATION

by D. S. DAVIS

(Head, Department of Pulp and Paper Technology, University of Alabama)

For many compounds, the molal entropy of vaporisation at the normal boiling point (TROUTON'S "constant") can be approximated when one knows the critical temperature and pressure. One uses a correlation given by REID and SHERWOOD,[2] the basis of the accompanying line co-ordinate chart, which was constructed by means of well-known methods.[1]

Use of the chart is illustrated as follows: What is the molal entropy of vaporisation of 1-butene at the boiling point, 267°K, if the critical temperature is 420°K and the critical pressure is 39.7 atm.? As shown by the isopleth, connect 39.7 on the critical pressure scale and 0.636, the ratio of 267 to 420, on the ratio scale with a straight line. Extend this line to meet the entropy scale at the desired value, 20.1 cal/(gm mole) (°K).



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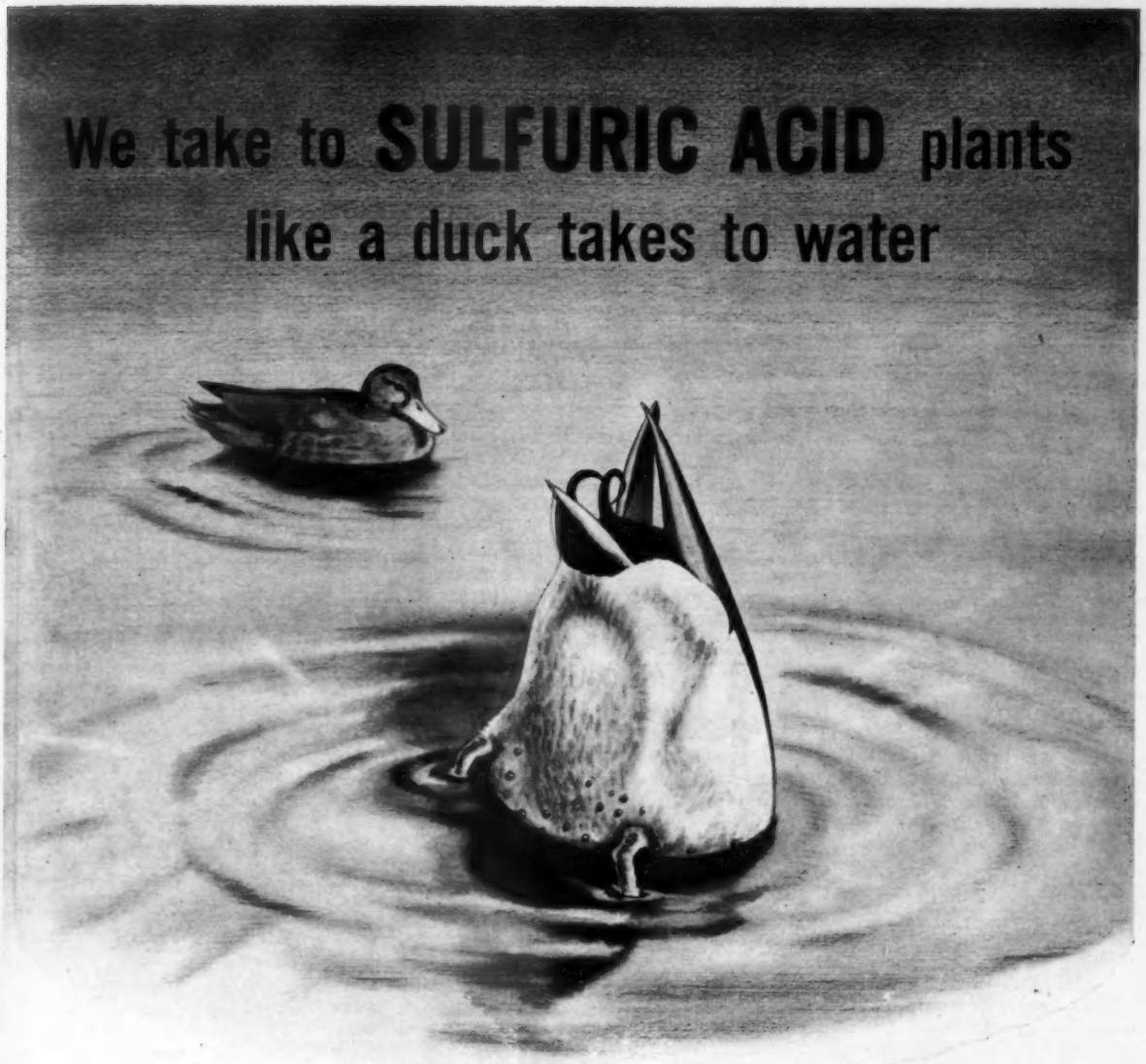

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AMERICAN LETTER

Recent Developments in Extraction Processes

THE ability of living organisms to thrive under apparently toxic conditions is always of interest and this particularly applies to an unusual case in Western America. This is a strain of bacteria known as *Thiobacillus Ferroxidans*, which is found in the acidic, copper-containing mine waters of Bingham Canyon, Utah, and it has already found a commercial use. This was recently disclosed in U.S. Patent No 2,829,964, wherein the researchers of the Kennicot Copper Co. refer to the ability of several strains of iron-oxidizing bacteria, such as the above, to live and multiply in relatively high concentrations of sulphuric acid and dissolved copper. It is said, as a consequence, that these organisms can be used to leach and recover such metals as copper, molybdenum and zinc from sulphide, and mixed oxide-sulphide ores.

For many years, waste water from certain copper mines has been percolated through old ore dumps to leach out the residual copper, which is then recovered from solution by precipitating with scrap iron. In some cases, the low-grade copper deposits have been leached *in situ* by such means, but this method is regarded as being, in general, far too slow. A recent development of this technique is the in-place leaching of stock-piled uranium ores mixed with pyrite by rain water which is said to recover 60 to 80% of the required components. Iron-bearing chromite and titanium ores can also be up-graded after roast reducing, by leaching out the metallic iron with ferric sulphate. Another application is the removal of impurities from electrolytic zinc and magnesium solutions by ferric sulphate.

In all of these cases, the ferric iron is changed to ferrous iron during the extraction process and the major deterrent to a widespread application has often been the difficulty of reconverting the ferrous sulphate in the spent lixiviant to ferric sulphate. Regeneration can be assisted by blowing air and sulphur dioxide into the solution, but the provision of a source of SO_2 has been an obstacle. However, *Thiobacillus Ferroxidans* has been found to oxidise ferrous solutions much more rapidly than chemical means, and, in addition, will promote the solution of numerous metallic sulphides. In some instances, the free sulphuric acid present is consumed in the leach process without a corresponding change in the iron content of the solution and the ferric sulphate may hydrolyse, liberating free sulphuric acid if enough iron be present. Such hydrolysis can promote savings in the sulphuric acid otherwise required. Iron can often be added in the form of pyrite if necessary.

Operating conditions when employing *Thiobacillus Ferroxidans* are said to be relatively broad. Temperatures should not exceed 40°C and materials such as redwood or certain phenolic resins should not be used in equipment, as these are harmful to the bacteria.

Hydrogen Iron

During the last decade, many schemes have been proposed in the U.S. and Europe for the production of iron and steel by means other than the classical blast furnace and converter or open-hearth route. A major incentive towards finding a satisfactory alternative has been the rapidly rising cost of new blast-furnace installations and associated items such as coke ovens, refractory plants and sintering units. However, the huge investments in existing capital equipment (and in some cases the possession of captive coal mines and other resources) will preclude a rapid transition to a new method, however successful it might be in reducing capital and operating costs.

One of the most promising developments in this field is the Hydrogen or H-Iron process, which is a direct outcome of collaboration between the petroleum industry and steel interests, and should prove of mutual benefit. This process is based on the reduction of finely powdered ore by recycled hydrogen at 500 psig or so, and at about 1000°F. The water of reaction is removed from the hydrogen stream by cooling and refrigeration, and a conversion efficiency between 7 and 10% per pass is attained according to the ore and other factors.

The need to use finely ground ore is not a handicap, since modern beneficiation methods produce fine material in the first place. Moreover, this permits fluidised handling and processing techniques to be used, which greatly facilitate automation. At the same time, the necessity for a sintering plant as used in blast furnace operations is avoided. In large operations, "dense phase" transportation and handling methods can be employed without the need for aeration to provide the necessary fluidity, since, provided the material is dry and under a sufficient gas pressure differential, it will flow freely at low velocity and high density, with a corresponding reduction in equipment sizes.

The H-Iron process is very similar to the hydrogen reforming system used for naphtha stocks and, indeed, much of the technique has been based upon standard refinery operations. Reduction is performed in several fluidised beds inside a reactor, with hydrogen flowing in counter-current fashion. The reduced charge is periodically dumped from the bottom bed of the reactor, while fresh ore is fed into the top of the vessel and moved downward from bed to bed. The reduced iron powder is transported to an agglomerating press and the piglets produced are subsequently added to an electric steel furnace charge. The reducer capacity is said to range between four and seven tons of iron per sq. ft per day, which is comparable with blast furnace operation. Wet hydrogen leaves the reducer at about 900°F and is cooled by heat exchangers, direct water contact and Freon refrigeration to reduce the free-water content to 0.01-0.02% by volume.

The first commercial H-Iron plant will soon be in operation in a Pennsylvania steelworks, following successful joint piloting by Hydrocarbon Research Inc. and the Bethlehem Steel Steel Co. The process is being closely watched, not only by steel producers but by the natural gas and petroleum industries as well, since it offers a favourable outlet for natural gas and certain refinery products, particularly as an alternative to ammonia manufacture. It is estimated that the total current pig iron production of some 75 million tons per annum would be equivalent to only 10% of present-day natural gas consumption, so that no adverse effects on other natural gas-consuming interests should result. Undoubtedly, an extremely promising future for this process lies ahead.

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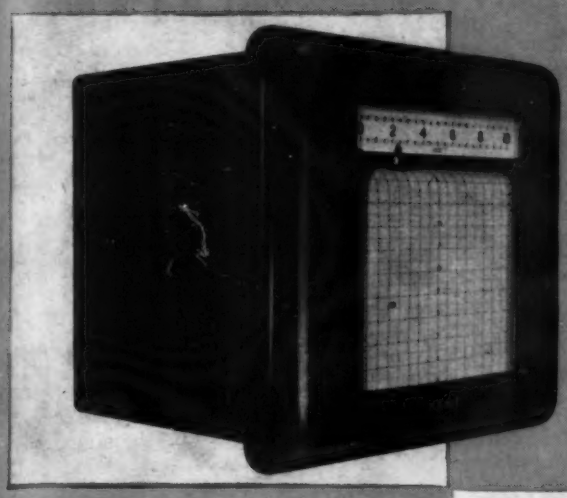

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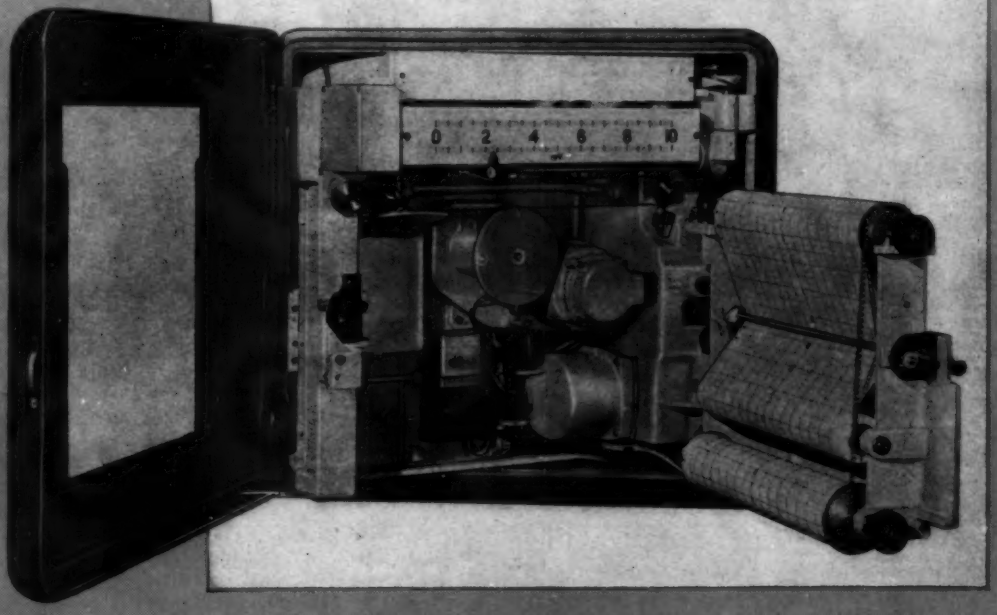

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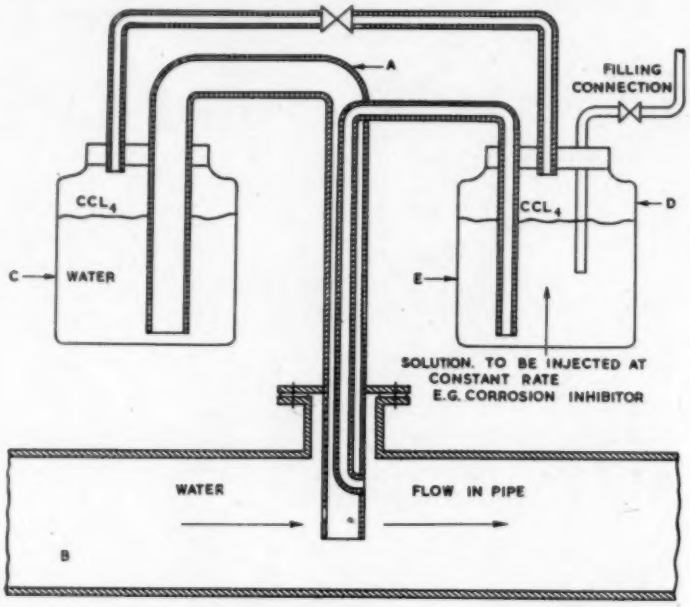
PROCESS ENGINEER'S NOTEBOOK

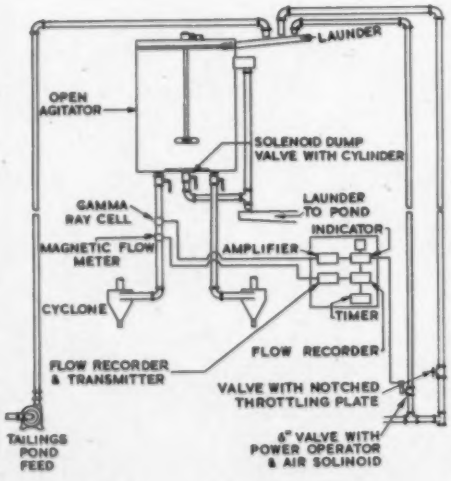
Treating Boiler Feed Water

IN THIS NOTEBOOK there appeared recently (*Brit. Chem. Eng.*, **4**, 3, p. 170) details of a preparation for treating boiler feed water. Here we describe a simple method for introducing this preparation, a Calgon-zinc chromate solution, into the low-pressure boiler feed water. The device illustrated, which incorporates a pitot tube element, makes use of the difference between total pressure exerted by the fluid at the opening facing the direction of flow and the static pressure exerted at the outlet of the inner connection. This pressure difference causes water to enter one of two containers, C and D. The former initially contains an organic liquid lighter than water and immiscible with it. The water entering C displaces the lighter liquid into D, and thereby forces the solution out of that container into the main water stream. The feed rate of this solution can be fixed by the position of the opening facing upstream, the maximum rate being obtained when it is in the centre of the pipe and the minimum when it is adjacent to the wall.



Control of Hydrocyclone Pressure

THE EFFICIENCY OF hydrocyclones depends upon the accurate regulation of inlet pressures. In cases where hydrocyclones are fed by centrifugal pumps, it is important that the pump sump levels do not vary widely. This condition is ensured by returning the slimes from cyclone to the pump sump behind a deep baffle. The sump is connected to the slimes pump sump by an overflow connection and in the event of any irregularity in the feed to the hydrocyclone feed pump, the slimes provide the make-up volume necessary to maintain a constant head to the hydrocyclone pump suction.



Where cyclones are fed by gravity from large vessels, nuclear density controllers may be used to control the cyclone feed pressure. The diagram shows a nuclear cell clamped to the cyclone feed pipe. The radiation passing through the pipe is measured, amplified, and used to actuate an electrically-operated valve which adds or restricts the amount of fresh water delivered to the feed tank. In this way the density, and therefore pressure, exerted by the suspension at the cyclone inlet is maintained constant. The fresh-water lines are shown at the right in the diagram.

Blockages in Distillation Columns

THE PLUGGING of the trays of distillation columns by corrosion products is common to quite a number of different industries and is a nuisance leading to irregular shut-downs and consequent loss of production. The problem is not always solved by the use of inhibitors to the charge material and the fabrication of the overhead condenser reflux pump and run-down lines where most of the corrosion products may be formed in corrosion-resistant materials is not always considered economic. One method of reducing the nuisance is to settle out the corrosion products at some point or points in the column where they cannot cause trouble and then remove them as part of the normal maintenance schedule.

The type of settling unit employed is shown in Fig. 1. If the column has bubble-cap trays, then either one of the trays from the actual column or a spare tray might be converted by removing the bubble caps, blanking-off some of the risers and extending

some of the others as shown in Fig. 1. The downcomer from the tray above should be shortened, otherwise solids will collect at the bottom and there would be little advantage in using the settler. The overflow weir will also have to be increased in height to produce a settling tank of suitable size which will allow the solids to settle out and accumulate for a reasonable period of time. A manhole cover should also be included in the design to permit the periodic removal of the solids. It is advisable to fit a settling tank above the top tray in the column to remove corrosion products entering from the condensing circuit. Others might be required within the main column.

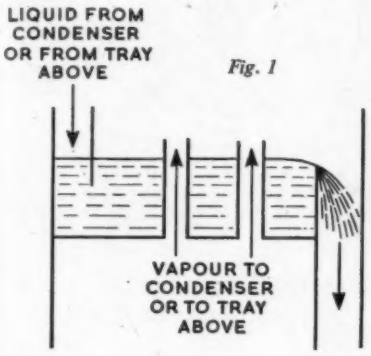
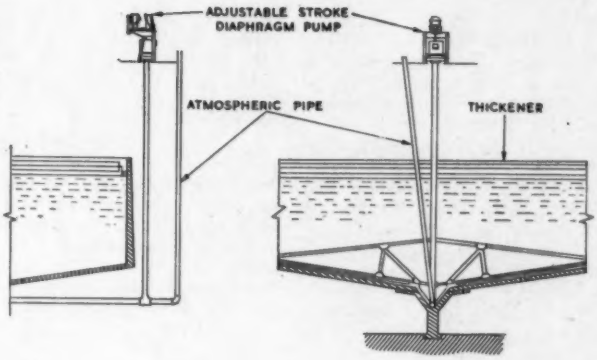


Fig. 1

P. E. BARKER

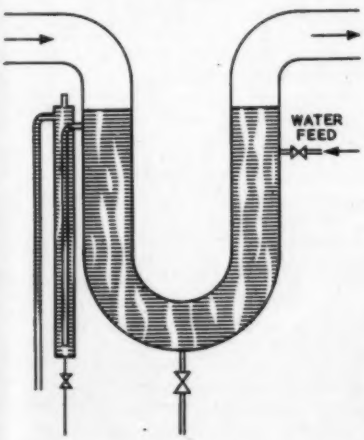
Increased Capacity for Diaphragm Pump



THE PIPEWORK MODIFICATION described here was first put into use at a 600-metric-ton-per-day Spanish Gold Cyanide Plant. In order to obtain complete gravity flow between counter-current decantation thickeners, adjustable-stroke diaphragm pumps were installed. These had to operate against a suction lift of approximately 8 ft compared with the more usual 3 to 5 ft. When the pumps were adjusted with the stroke at the maximum, performance was fairly satisfactory, although situations were foreseen where greater deliveries would be necessary. Accordingly, in each case, the suction pipework was modified by fitting a tee-piece into which was screwed an open-ended length of tubing parallel to the main suction pipe. This modification proved to be very effective, so much so that, with the pumping stroke reduced to one-half the maximum, the capacity was 60% up on the capacity obtained previously without the "vent" pipe and when the pump stroke was at is maximum. In this particular installation, engineered by the Denver Co., four such pumps have been installed, each fitted with vent pipes. Their diameters are 1 in. less than those of the main suction pipes.

Sealed Loop Replaces Valve

IN THE TRANSFERENCE of large quantities of low-pressure gases, for example, at carbonisation plants, this device is a satisfactory alternative to the conventional valve and it has the advantage of providing the equivalent of a dead-tight seal without any of the difficulties arising from the deposition of tarry matter from the gases. The loop is constructed from large-diameter pipework and is filled with water when it is desired to isolate the section of the plant upstream of the loop from that downstream. The charge of water is drained from the loop when the gas is to be passed through the seal. The seal in the side arm prevents the leakage of gas to amosphere, the submergence of the dip-pipe being greater than the static pressure of the gas in the system. To restore the seal, water is added and the drain closed. The design of the side arm ensures that the correct water level is automatically established. One application for this valve-substitute is in coking plants where parallel and series operation of the oxide towers may be required.



This method of providing a closure or a throughway in a large-diameter pipeline was noted during a recent visit to the Fleck Gas Works, Walsall (West Midlands Gas Board), claimed to be the most modern of its kind in the U.K.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Fatty Acids

A new process of manufacture of a special type of fatty acids particularly useful in industry has been developed at the Shri Ram Institute for Industrial Research, Delhi. Besides several technical advantages, this process has developed an improved technique and results in useful by-products. The process has been studied on a pilot-plant scale where batches of 6-8 lb. of fatty acids have been processed and sufficient data collected to scale-up to commercial size. Conditions for preparing alkyds and polyesters, using these finished fatty acids, have been standardised, and work on the preparation of polyamides and similar other products is in progress.

New Extraction Processes

Following the discovery that Hungarian bauxite contains a useful concentration of gallium, chemical engineers attached to the Institute of Metal Research set out to develop a process for its extraction. After considerable experimentation, a process has been evolved which allows gallium to be produced alongside alumina production without interference to the latter. A plant incorporating gallium extraction is now operating in a wing of the Ajka Alumina and Aluminium Plant and has been assembled in its entirety from Hungarian plant designs, fabricated in Hungary.

Another process of recent origin extracts sugar from beet slices by means of a continuous process. In the new process developed by the Hungarian Institute of Sugar Research, the most novel feature is the diffusion device which consists of a large U tube which has one of its limbs truncated. The beetroot slices are carried slowly downwards into the shorter arm by means of chain-driven iron wheels and after passing through the bottom bend the slices are lifted to the opening at the top of the upper arm. At this stage the slices are completely leached. Where the water feed is introduced it is claimed that the labour of four labourers per shift is saved by this new process.

German Petroleums

The first four of a number of new petroleum chemical production units being built for Erdolchemie G.m.b.H. at Dormagen, near Cologne, Western Germany, have been commissioned. Erdolchemie is a jointly-owned company in which BP's German associate, BP Benzin und Petroleum A.G., and Farbenfabriken Bayer A.G. each have a 50% interest. Ethylene and a variety of other gases used as basic chemical raw materials are being produced from a cracking plant and gas separation plant. Another cracking plant is being erected and the output of ethylene from both plants will total about 45,000 tons a year. The major part of the ethylene produced will be transformed to ethylene oxide in two plants, the first of which has been commissioned. They will have a total capacity of about 36,000 tons a year of ethylene oxide, which is used, among other things, in the manufacture of synthetic resins and detergents. The balance of the ethylene will be used for the manufacture of synthetic ethyl alcohol. A large part of the ethylene oxide produced is being processed in a glycols plant. The product from this plant may be used in the manufacture of anti-freeze, plastics and synthetic fibres.

Chemicals Retain Lead

The increase in the number of applications for patents, according to the annual report of the Indian Patent Office for 1957 which surveys the trend of inventions during the year, was 3456 in 1957 from 3067 in 1956. The chemical industry retained its predominance in inventions which related mainly to dyestuffs, natural and synthetic drugs, hormones, and synthetic resins. Indian inventions were mainly for the manufacture of porous polymer from cashewnut-shell oil, exchange resins and protein hydrolysates. The metallurgical industries, particularly iron and steel, attracted several applications from abroad, some of which related to improved processes of extraction of iron from ores, and refining of pig-iron and steel. Interest was also shown in different types of furnace.

French Natural Gas

It is reported that Europe's largest plant for the treatment of natural gas is well advanced at Lacq, France. This stage, which will carry output up to 2000 million cu. m. of purified gas a year, should be completed ahead of time, possibly in November. In 1961, the fourth and final stage will come into production, raising the output by 4000 million cu. m. of purified gas a year, plus 130,000 tons of propane and butane, 260,000 tons of petrol and 1.4 million tons of sulphur.

Healthy Monsanto

Sales of products of the Monsanto Chemical Co. in the first quarter of 1959, including its domestic and foreign subsidiaries and its 50% share of the sales of associated companies, amounted to $197,842,000, an increase of 23% over sales during the same period last year.

Net earnings from such sales were $15,768,000, an increase of 107% over the earnings for the first quarter of 1958. These earnings are, after allowance for taxes, equivalent to 71 cents a common share on 22,301,900 shares outstanding. In the first quarter of 1958 such earnings were equal to 34 cents a share on 22,256,600 shares.

New Zealand's First Refinery

Construction is expected to begin at an early date on New Zealand's first oil refinery, and a survey is to be undertaken immediately to decide upon a suitable site for it. To be built by Shell at an estimated cost of approximately £17 million, the new plant will have an annual capacity of 2 million tons. In preparing its plans, Shell has had to overcome certain unusual problems—New Zealand's peculiar pattern of demand, which is complicated by disproportionately high consumption of petrol, and its geographical position, which militates against the economic export of surplus products. In addition, the refinery has been designed with sufficient flexibility to process a wide variety of crude oils including, so far as possible, any that may in future be found within the country, if the present search, in which Shell is also participating, meets with success.

The first 15 of 47 English Electric transformers being supplied to Nangal Fertilisers & Chemicals (Private) Ltd. being loaded on the Indian Pioneer *at Birkenhead. They will be installed at a fertiliser plant at Nangal in the Punjab to supply d.c. power for the electrolytic production of hydrogen and heavy water. The contract to supply the complete electrical equipment for the plant is worth about £1½ million.*

Australian Oil

The Australian oil industry is to spend about £A61 million on expansion during the next two years. The Petroleum Information Bureau of Australia has announced that the programme would increase output by more than 15 million tons. Additions to Australian refineries in recent years have enabled the various companies to process 89% of the country's petroleum products. Future plans include a provision for doubling the present capacity of the Kurnell refinery in New South Wales to a total of more than 4 million tons a year and the erection of a new refinery in South Australia, which would handle 1,500,000 tons.

Indian Fertilisers

The Minister for Indian Industries said recently that every State in India would have one fertiliser plant by the end of the third Five-year Plan. He said the Government hoped that the Andhra State would have a fertiliser factory and that it would be started very soon. He added that, in addition to major plants, it was also proposed to establish a number of minimum plants because such plants were essential for the industrial progress of the country.

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Agents in Belgium, France and Holland: FOURS LECOCQ ET ATELIERS DE TRAZEGNIES REUNIS, S.A., TRAZEGNIES, BELGIUM

Book Reviews

Russian Courses on Theoretical Physics: Statistical Physics
by L. D. Landau and E. M. Lifshitz: translated by E. Peierls and F. R. Peierls
Pergamon Press, London, 1958, 482 pp., 80s.

Quantum Mechanics (Non-Relativistic Theory)
by L. D. Landau and E. M. Lifshitz; translated by J. B. Sykes and J. S. Bell
Pergamon Press, London, 1958, 515 pp., 80s.

THESE two volumes are part of a series of nine volumes on theoretical physics, which is planned to include volumes on mechanics, the classical theory of fields, quantum mechanics (as above), relativistic quantum theory (not yet written), statistical physics (as above), fluid mechanics, theory of elasticity, electrodynamics of continuous media, and physical kinetics (not yet written). In view of the very wide scope of modern theoretical physics, the authors have made no attempt to discuss all that might be included under any of these titles. One of their principles is not to deal with topics which could not properly be expounded without at the same time giving a detailed account of existing experimental results. This avoids the empirical frontiers of much chemical physics and the greater part of nuclear physics. In their selection of topics, very complicated applications of theory likewise tend to be avoided, in order to deal as fully as possible with those topics that have been included.

References to other works and to original papers are only given if this helps the teaching functions which the authors clearly have as their primary objective in writing this series. The English versions of the volume on statistical physics (translated with some revision from a new Russian text) and of the volume on quantum mechanics (translated from a Russian text published in 1948) are clear and readable. They constitute very acceptable alternative texts, and in some sections primary reference texts, in the teaching of theoretical physics. Their very marked bias away from confrontation with experimental findings is, however, not a desirable feature for the training of those British theoretical physicists (one hopes they will be numerous) whose work is destined to interact strongly and fruitfully with that of experimentalists. And, again, some perspective about dates and authorship of major advances in physics is best acquired even at the learning stage, where the present texts will be most frequently consulted. Not to learn the habit of scanning world horizons in the advancement of science can become a serious deficiency.

The volume on statistical physics contains valuable features not always dealt with at comparable length in English text-books of about the same standard. Chapters on the theory of fluctuations and on "second order" transitions are notable examples, and there are useful discussions of systems at high temperatures or undergoing rotation. The volume on quantum mechanics contains much that is by now incorporated in various text-books in Engish, though it is convenient to have this material in the present form. Both volumes have many marks of having been written by leaders in their chosen fields, and are desirable additions to university libraries.

A. R. UBBELHOHDE

The Industrial Cooling Tower
by K. K. McKelvey and M. Brooke
Elsevier Publishing Co., London, 429 pp., 93s

THE authors have brought together a wealth of theoretical and practical data on cooling towers of all types that has previously been widely dispersed in journals and pamphlets, and they have added to it information and data from their own experience in this field. The whole range of cooling tower theory and design is considered and among the contents are chapters dealing with psychrometry, heat transfer in cooling towers, practical engineering calculations and cooling tower economics. The book is primarily written for designers and builders of cooling towers, but will prove of immense value to the practical works engineer, as it gives some very useful information on such items as water treatment, blowdown, and details of maintenance schedules for this much-neglected item of equipment.

Natural-draught hyperbolic towers are dealt with in great detail and there is a chapter mainly devoted to the construction of these towers. Two economic assessments are made between hyperbolic natural-draught and mechanical-draught towers for power station duties, which both appear economically favourable to natural-draught towers. However, the dimensions of mechanical-draught towers selected are very uneconomical for the duty and it is not pointed out that the temperature conditions for this type of duty are advantageous to natural-draught towers. The impression given, therefore, is that concrete natural-draught towers are the most economical and the main ones in use, whereas induced-draught towers are a very large percentage of those being supplied to industry in this country and Europe and this percentage is increasing. In fact, mechanical-draught towers often prove the only possible choice for many industrial duties.

The various types of cooling tower packings are analysed, but no mention is made of plastic packings which have been used in many installations in America for the last two to three years with outstanding results. One further section which would have proved of use to potential cooling tower users is one which would assist them in selecting the most economic water flow and temperatures for a specific function, heat load and yearly coverage. However, these are minor criticisms of what is otherwise an excellent book which should be possessed by everyone who has any dealings with cooling towers, either as a designer or a user.

A. A. BRISCOE

Flow Measurement and Control
by W. F. Coxon
Heywood & Co. Ltd., London, 312 pp., 55s.

THIS, the third volume in the new series "Physical Processes in the Chemical Industry", attempts to give an elementary introduction to the industrial applications of flow measurement. The book consists of 10 chapters and an appendix. The early chapters, after considering the types of fluid meters and the elementary theory, discuss installation of fluid meters both in general and in specific processes—blast furnaces, boiler houses and pumping stations. Little attempt is made to deal with the theory of automatic control in general terms, except for brief mention of some types of control. The book is directed more at the student in "sandwich" and H.N.C. courses, who would not have the mathematical background for a more advanced treatment. It tends, therefore, to be an amplification and application of the principles of B.S. 1042, a fact emphasised by the details of the revised version of B.S. 1042 given in the appendix. The text does not set out to inspire new types of instruments, or to direct complex plant instrumentation, but acts as an introduction to the practical aspects of instrumentation for flow measurement, which would be greatly appreciated by those entering the chemical industry for the first time.

W. STRAUSS

British Standards

B.S. 3116: 1959. Heat-sensitive Detectors for Automatic Fire Alarm Systems in Buildings. 4s.

THE purpose of this standard is to specify a series of type tests by which the satisfactory operation of heat-sensitive detectors other than line detectors of automatic fire alarm systems in buildings may reasonably be ensured. There are two classes of heat-sensitive detector, the "point" or "spot" detector which, as the name implies, is relatively small and is affected by the hot gases from the fire at one point on the ceiling and the "line" or "continuous" detector. The latter has not been included in the present edition of this standard.

Shorter Notices

Government Publications: Department of Scientific and Industrial Research. Sectional List No. 3. Revised to November, 1958. H.M.S.O. 1959.

REPORTS of the work of the D.S.I.R. appear in the publications of learned societies and professional institutions, in the scientific, technical and trade periodicals or as publications of H.M. Stationery Office or the Department. This list contains publications which are issued by H.M. Stationery Office or the Department which are still in print or in the press and have been graded as follows:

(a) Suitable for an intelligent reader who has no previous knowledge of the subject.
(b) Suitable for a senior student or practitioner of the subject.
(c) Suitable for research workers and specialists in the subject.

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This book has been specially designed to help all scientists who want to be able to read German scientific texts and wish to reach this limited aim by the shortest route. It differs, therefore, from the usual grammars. The reader is introduced to the *written* language, and the main emphasis of the book is placed upon those aspects of grammar that must be known if one is to *read* German, while those that are only needed to speak or write it correctly are passed over lightly.

★ ★ ★

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(General Electric Company)

278 pages *Illustrated* *48s. net*

The scope of this work includes the manufacture, properties and applications of the silicones; with data on the properties of silicone resins, fluids and rubbers at high temperatures. It contains case histories of present industrial applications, and many new ones, and will be of interest to design engineers, formulators and manufacturers in all industries who might have interest in silicones as engineering and raw materials.

INDUSTRIAL FATTY ACIDS and their Applications

Edited by

E. SCOTT PATTISON

(Manager, Fatty Acid Producers Council New York)

236 pages *Illustrated* *56s. net*

This book covers the production and processing of fatty acids with emphasis on practical technology and the chemistry involved with it. It also includes an up-to-date review of the chemistry, technology and applications of the derivatives having commercial importance. The growing importance of fatty acids derived from tall oil—one of the most recent advances—is also dealt with.

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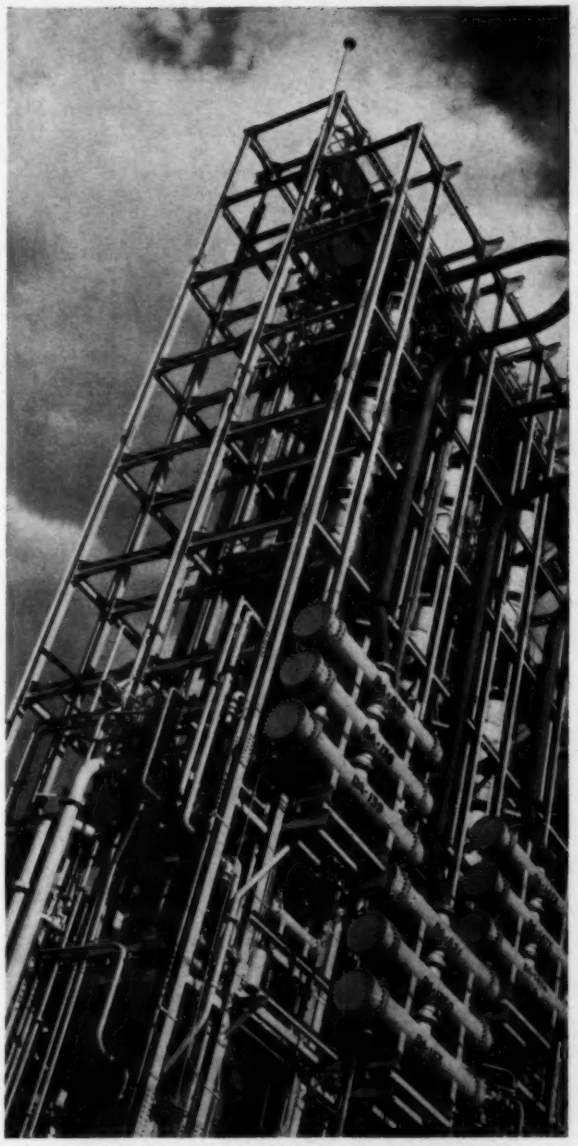

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PLANT EQUIPMENT NEWS

MIXERS

Vibratory Mixers

Vibrating mixers now challenge the long-established rotary machines. The range of "Vibromix" units recently introduced to the British market employ for their basic agitating element a perforated plate fitted to the end of a shaft which vibrates at a.c. mains frequency along the axis of the motor shaft. An important feature of this plate is the effect of tapering the holes; thus if the taper is upwards the fluid is forced upwards, and vice versa. The amplitude of vibration may be varied at will from 0 to $\frac{1}{8}$ in. The liquid in the vessel is not only circulated rapidly, but is subject to impact and a high degree of local turbulence at the plate, and through the considerable shattering effect exerted by this agitator agglomerations of solid particles suspended in the liquid are rapidly disintegrated. It does not form vortices and is equally effective as an emulsifier, as a producer of suspensions and as a gas liquid contactor. In the latter case, a hollow shaft may be used through which the gas is introduced.

By means of a diaphragm sealing unit it is possible to use the vibrating plate inside closed vessels, either under high vacua or at pressures up to 100 psi. Special units are available for pressures up to 6000 psi. A noteworthy practical point is the easy removal of the vibration head. When in use the latter is suspended from a hook and is disconnected from the shaft by loosening the coupling screw and lifting the head from the hook. Industrial units suitable for installing in vessels of volumes of from 4-1000 gal. are now available, the prices varying from £122 to £310. A useful small capacity vibrating diaphragm pump is also available. In the case of the closed-circuit transfer version of this pump, the output is 300 ml/min. under a 150-cm head of water. **Shandon Scientific Co. Ltd., 6 Cromwell Place, London, S.W.7.**

BCE 5704 for further information

Hydraulic-lift Mixer

New from Cox's Machinery is the Dualmix 50-gal. mixer. It is designed so that the mixing pans may be easily changed, and the mixing is effected by the use of a central paddle and peripheral adjustable rotating scraper blades. The drive is by a 15/7½-hp two-speed motor and hydraulic cylinders are used for elevating the head for positioning or removing the container. The complete machine is controlled by push buttons or finger-operated levers. **Cox's Machinery Ltd., 25 St. Thomas Street, Bristol, 1.**

BCE 5705 for further information

Turbine Mixers

Quick-release couplings to allow mixer shafts to be changed rapidly and the absence of vibration through dynamic balancing are among the commendable features of a wide range of mixers now being manufactured by Aiton & Co. One section of the range available covers horsepowers of from ¼ to 3, the agitation being provided in each case by an angle-bladed turbine impeller fitted with a stabiliser ring. Speed of rotation is either 1400 or 900 rpm. The stabiliser ring is particularly useful when it is necessary to discharge the contents of a vessel while the agitator is still in motion. The shaft and impeller are made from FMB grade stainless steel, and other materials of construction may be used if required. The mixers may be portable or permanently fixed to a vessel.

In the design a great deal has been done to eliminate vibration, and the makers have been able to show very convincingly that the occurrence of vibrations, apart from its harmful mechanical consequences, seriously delays the actual mixing process. Thus, on tests to show the effect of vibrations upon the rate of dissolution of sodium metaphosphate in a 300-gal. charge of water, using a ½-hp mixer, it was found that the solid charge of 4 lb. was completely dissolved in about 10 min. when the amplitude of vibration at the bearing fitted below the coupling shaft was 12 microns. When the vibrations were allowed to increase in amplitude to 400 microns, the time to dissolve completely increased to about 15 min., so that power consumption for the preparation was about 70% greater.

Other recently introduced models produced by Aiton include side-entering mixers which allow the shaft glands to be packed while the vessel is still full of liquid, and a new lightweight series for horsepowers ranging from ¼ to ½. In addition, individually-tailored mixers in sizes represented by ¼ to 100 hp can be designed for either open or closed vessels for operation under vacuum or pressure and employing turbine, propeller or other type impellers where appropriate. Since the company has extensive fabricating facilities, and will also design the vessels, they are able to offer co-ordinated designs of processing vessels. **Aiton & Co. Ltd., Derby.**

BCE 5706 for further information

Vibratory Grinder-mixer

The vibratory mill introduced recently by William Boulton has been developed for the paint industry for combined grinding and mixing. Mixing is aided by a spiral, inclined plane built within the chamber of the mill. The gyratory movement causes the solid matter in the chamber to climb the plane and to cascade from its end. **William Boulton Ltd., Providence Engineering Works, Burslem, Stoke-on-Trent.**

BCE 5707 for further information

PUMPS AND FANS

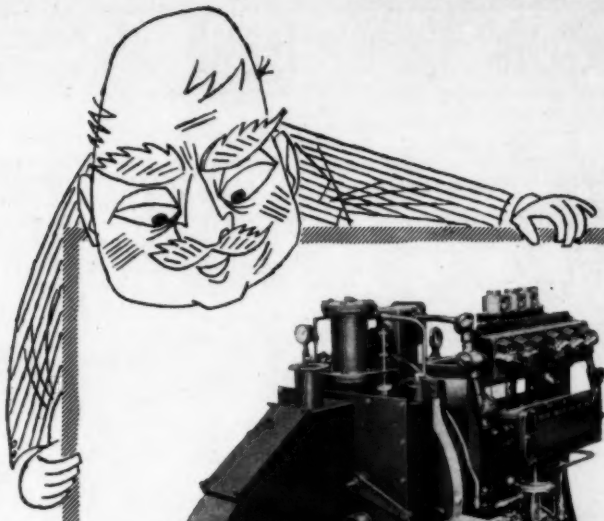
Graphite Pumps

The Union Carbide International Co. has added three new models to its range of pumps made from standard parts of low-cost Karbate impervious graphite, giving the greater capacity range demanded by the chemical and metal-finishing industries. Models 22-FAL and 31-FAL are fitted with 1-, 1½- and 2-hp motors. At 1750 rpm maximum heads are 33, 51 and 67 ft with delivery for the latter two sizes up to 150 gpm, compared with 80 gpm for previous type F Karbate pumps. Similarly, at 1450 rpm maximum heads are 22, 34 and 45 ft respectively. The two larger sizes can be fitted with 3-hp or 5-hp motors for pumping liquids with a specific gravity greater than 1. **Union Carbide International Co., 30 East 42nd Street, New York, 17, U.S.A.**

BCE 5708 for further information

Corrosive Liquor Pumps

Kestners are producing a new range of horizontal centrifugal pumps of robust construction. The rigid bearing assembly in cast iron, with totally-enclosed bearings, has no pockets in which corrosives can collect; it may be used with either V-rope or direct motor



New Sharples Super-D-Hydrators

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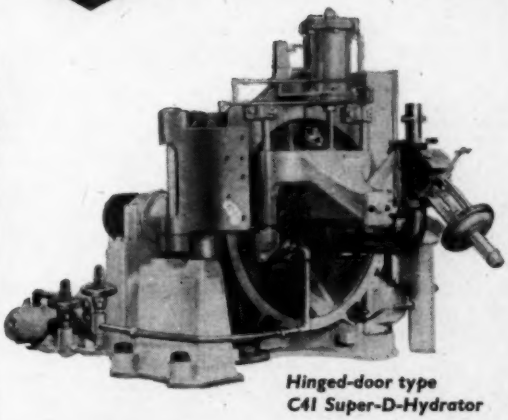
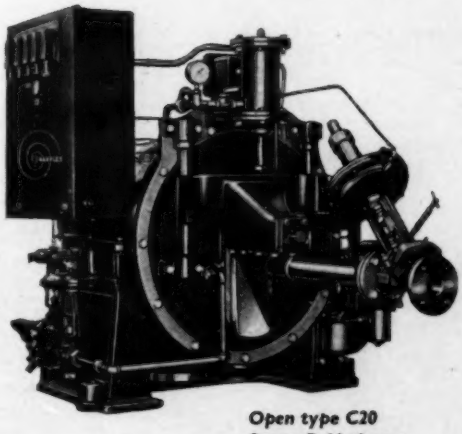
Enclosed type C27 Super-D-Hydrator



Hinged-door type C41 Super-D-Hydrator



Open type C20 Super-D-Hydrator

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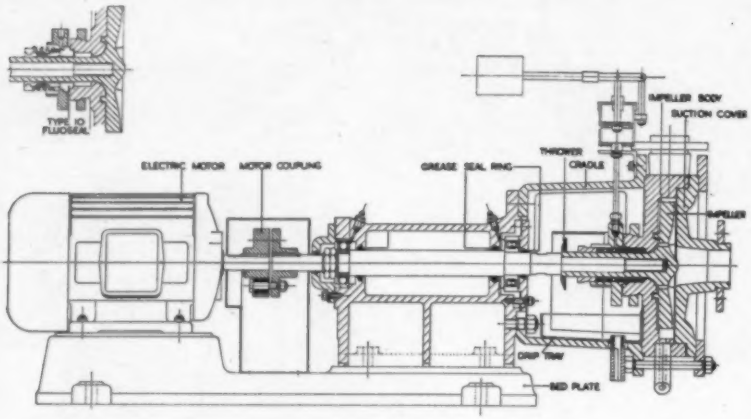
PLANT EQUIPMENT NEWS



drive. The design allows maximum interchangeability of different contact materials including Keebush. For shaft sealing a packed gland, a Type 10 Crane or Flexibox mechanical seal can be used as desired. The generously sized shaft reduces orbital movement—an important consideration for counteracting seal wear. An example of the more difficult liquids pumped is Merilene heat-transfer oil at 600°F in a cast steel pump fitted with water-cooled Flexibox seal and direct motor drive. **Kestner Evaporator & Engineering Co. Ltd., Grosvenor Gardens, London, S.W.1.**

BCE 5709 for further information

P.V.C. Fans

Acalor (1948) Ltd. announce in conjunction with The Sturtevant Engineering Co. Ltd. that they have now produced a new range of fans to handle corrosive fumes and gases. They have an all-P.V.C. casing with clad impeller, the unit being of very robust construction. The new design offers an alternative to the all-fabricated P.V.C. fans made by the companies and has the advantage of safe, high operating speeds; an all-P.V.C. fabricated impeller will shortly be available if desired. **Acalor (1948) Ltd., Kelvin Way, Crawley, Sussex.**

BCE 5710 for further information

Chemical Solution Feed Pump

Fischer & Porter has introduced a new chemical solution feed pump that features a hydraulically-balanced Teflon slack diaphragm. The diaphragm is not connected to the plunger and is unconditionally guaranteed for the life of the pump. The rate of the pump, which operates at 70 strokes per minute approaching continuous flow, can be manually adjusted during operation or while shut-down. The new pump has a capacity of 54 Imperial gallons every 24 hours, an operating pressure up to 125 psi and a maximum continuous temperature rating of 100°F. It will handle alum, acids, hypochlorites, polyphosphates, soda ash, fluorides and similar materials. **Fischer & Porter Co., 28 Jacksonville Road, Hatboro, Pa., U.S.A.**

BCE 5711 for further information

A Safe, Portable Barrel Pump

The British Central Electrical Co. Ltd. has just added to its portable barrel pump range an air-motor-operated unit suitable for discharging the contents of barrels under hazardous conditions. It is operated by a high-efficiency air motor using air at 30-120 psi, a reducing valve being unnecessary. An outer suction tube fitted with hose attachment, for 1¼-in. bore hose, allows the liquid to be raised into a standard hose line. The consumption of the air motor with such liquids as water is approximately 20 cfm from an 80 psi air line. The motor is controlled by a simple handgrip, which can be locked in position if desired.

The lifting tube sets are detachable and are easily dismantled for cleaning and sterilising all parts in contact with the liquid. Tube sets are available in two lengths—2 ft 3 in. and 3 ft 7 in.—in aluminium alloy; also 2 ft 3 in. and 3 ft 11¼ in. in austenitic stainless steel (composition approximately 19% chrome, 13% nickel, 2·5 molybdenum and titanium) to enable it to be used with foodstuffs, acids and other corrosive liquids.

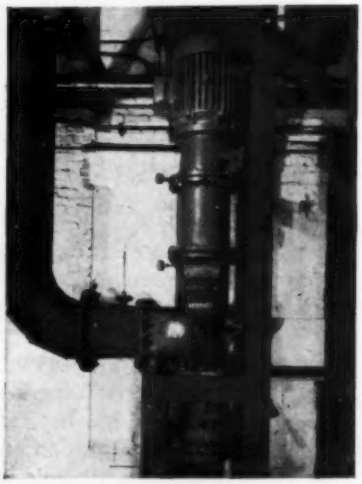
The unit is self-priming, and will operate against full pressure. It will handle most liquids, and deliver up to 2000 gph dependent on viscosity and lifting head, the maximum head being approximately 25 ft; the maximum viscosity approximately 150 degrees Engler, or SAE 30.

This pump, designated Type 400-PM, weighs no more than 11¼ lb. in all-alloy construction and costs £55 11s. It is also supplied in stainless steel at higher cost. **British Central Engineering Co. Ltd., 6 Rosebery Avenue, London, E.C.1.**

BCE 5712 for further information

Vertical Axial Flow Pump

Kestners are producing an interesting, large, vertical, glandless pump. Type H, of the axial flow propeller type with guide vanes on suction and delivery sides. It can handle 3300 gpm. The shaft is mild-steel sheathed in antimonial lead and silicon iron, the pump body is of regulus, while the guide vanes and pump casing, which is sleeved and jacketed for steaming out, is made of Tautiron (high silicon iron). This pump has no gland or bearing in contact with the liquor being pumped. For sealing the pump, a supply of "sealing" liquor is fed into the chamber adjacent to the sealing sleeve and the surplus is led away. Alternatively, the liquor can be arranged to make its own seal. **Kestner Evaporator & Engineering Co. Ltd., Grosvenor Gardens, London, S.W.1.**



BCE 5713 for further information

INSTRUMENTS

A new type (51) of integrating level detector has been recently introduced by 30-98. It makes possible on or off indication, even although the level may be fluctuating, while a bi-stable circuit gives a definite relay action which eliminates the effects of vibration. Contact resistance of up to ½ megohm is acceptable and allowance can be made for leakage resistance less than contact resistance.

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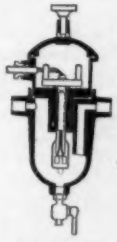
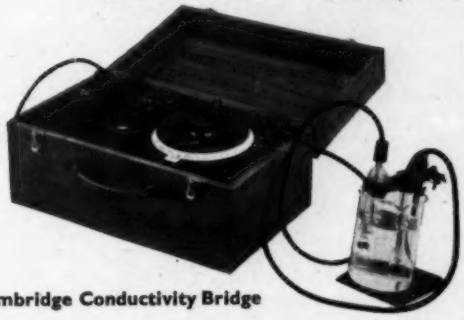


Continuous Flow Electrode System

Cambridge Electronic Recorder

(The Controller is almost identical in general appearance.)



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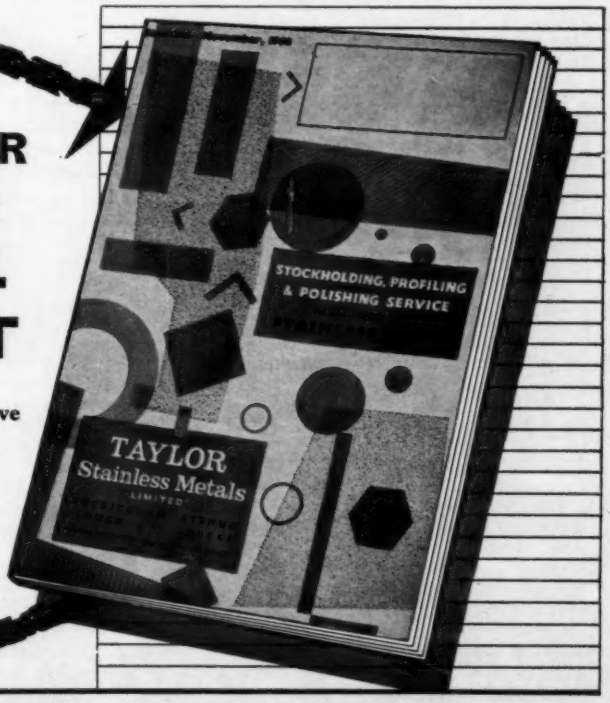

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BCE 5660 for further information

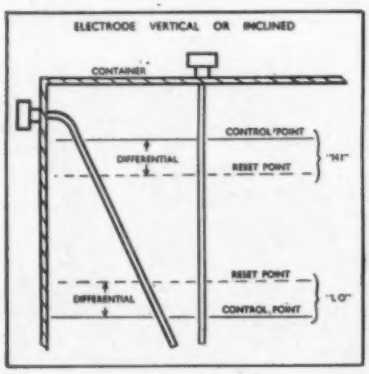
PLANT EQUIPMENT NEWS

The equipment will operate from 230 or 415 volts and make or break circuits up to 4 amps at 415 volts, or 12 amps at 230 volts as a simple detector or as a two-level interlocked controller. **The 30-98 Co. Ltd., Gatwick House, Lowfield Heath, Sussex.**

BCE 5714 for further information

Unique Level Controller

A significant contribution to the problem of controlling the levels of solids, of fairly viscous liquids, and for the detection of the build-up of precipitates is made by a recently-developed controller. The instrument, which operates on the capacitance principle, has outstanding flexibility and sensitivity. The former attribute has been effected by means of its continuously variable differential control. This makes it possible to choose from a wide differential capacitance range of 1-40 micro-microfarads by the adjustment of two simple controls. The first sets the control point of the relay included in the control system, and the second allows the reset point to be varied without altering the setting of the control point, and so determines the differential as required. These features widen the scope of the instrument, since it may be adjusted to give the best setting for each application, may be readjusted when plant conditions change without difficulty, and permit one instrument only to be used where two of the fixed differential type might normally be required.



This instrument, the "Leveltron", is highly sensitive and the long- and short-term stabilities are as follows: control point drift, given a steady supply voltage, is less than ±1 micro-microfarad over a period of three months, and for constant ambient temperature. For temperature changes of from 0 to −40°C the drift is less than 1 micro-microfarad. Differential drift under the same conditions is even less, and variations resulting from humidity are negligible.

A number of points of practical appeal have been incorporated in the design; thus measurement may be made as far as 60 ft from the point of detection; the measuring unit is located in the main control box and not in the electrode assembly. The transmission link system minimises the increased non-working capacitance of the greater cable length. Finally, there is range of electrodes to meet a variety of applications. The prices of these instrument controls range from £26-£46 and their design and manufacture is carried out by **Thomas Industrial Automation Ltd., Altrincham, Cheshire.**

BCE 5715 for further information

Technoscopes

At the recent exhibition held in London by Degenhardt, information on the Technoscopes for the examination of large cavities and the interior walls of tubes was released to the technical Press. The Technoscopes, manufactured by M. Hensoldt of Germany, are designed for the checking of rivets, joints, alterations of interior surfaces due to corrosion, cracks and porosities. The instrument consists of one eyepiece tube and one objective tube and a suitable number of extension tubes containing optical systems. The image of the object under examination appears in the field of view of the instrument in the same way in which it would appear to the naked eye if it were possible to place it at a distance of 10 in. from the object. Instrument diameters obtainable from 0.512-1.772 in. (13-45 mm) and lengths of tubes from 19.685-866.14 in. (500-22,000 mm). **Degenhardt & Co. Ltd., 6 Cavendish Square, London, W.1.**

BCE 5716 for further information

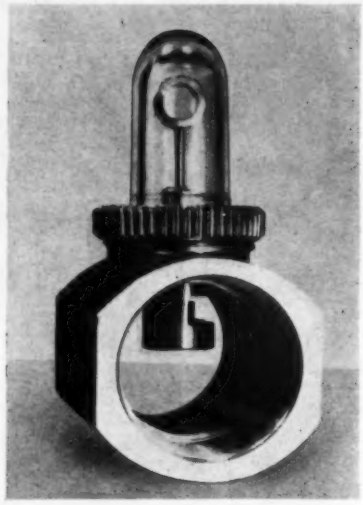
Turbine-type Flowmeter

Industrial gases such as sulphur dioxide, methyl chloride, ammonia, steam and chlorine can be handled by the Gas Pottermeter over a temperature range of −425°F to 1000°F in pressure ranges exceeding 25,000 psi. This turbine-type flowmeter is announced as having a phenomenally low pressure drop and an accuracy of ±0.5% or better of reading over a ten-to-one linear range, with excellent repeatability. Other claims are that it measures with high accuracy gases contaminated with solid particles such as pipe scale, organic sludge and similar troublesome conditions that seriously affect gas measurement by other primary devices. **The Pottermeter Co., Division of Potter Aero. Corp. Union, New Jersey.**

BCE 5717 for further information

Variable Flow Indicators

Walker, Crossweller have extended their range of Arkon variable flow indicators. These instruments can be adjusted for high or low velocities of flow and now include sizes 1½ in., 1½ in. and 2 in., in addition to ½ in., ¾ in. and 1 in. The principle of cartridge construction is used in these instruments. the complete cartridge assembly being interchangeable between the different sizes. The spindle impeller assembly, which is fitted in a cartridge housing, is easily removed and reset for the required flow range. The indicator shows at a glance whether flow is taking place and can be used to indicate the flow of water, lubricating oil, cooling oil and other liquids. A chromium-plated ring at the top of the spindle under a toughened glass dome stops spinning if the flow stops. **Walker, Crosweller & Co. Ltd., Cheltenham.**



BCE 5718 for further information

Average-temperature Gauge

The Evershed tank average-temperature gauge is designed for the measurement of the average temperature of liquids in fixed or floating roof tanks within the range 0-100°C. The equipment is suitable for working depths between 30 ft and 60 ft and can be used with all liquids which are inert to nylon, the material used for protecting the resistance thermometer elements. **Evershed & Vignoles Ltd., Acton Lane Works, Chiswick, London, W.4.**

BCE 5719 for further information

Flow Integrator

A unique method has been used in the Brooks MPT-53 flow integrator to translate the vertical motion of a rotameter metering float into a rotary motion.

The converter consists of a magnetic iron strip formed into a helix and enclosed in a non-magnetic stainless-steel tube mounted between two stainless-steel, miniature bearing races. The helix assembly is located parallel and adjacent to the rotameter extension tube. A metering float extension which has a magnet embedded in it moves within the tube in direct response to flow rate changes. The leading edge of the helix is constantly attracted to the magnet, thus turning to convert linear motion into a rotary one. The flow is integrated photo-electrically. Flow rate is indicated on a 4½-in. indicating scale and is totalised every three

BCE 5661 for further information

EXPANSION

VIBRATION

MOVEMENT

Can we help you with your pipe problems?

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians.

Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipework is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

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PLANT EQUIPMENT NEWS

seconds on a six-digit counter. **Brooks Rotameter Co., P.O. Box 432, Lansdale, Pennsylvania, U.S.A.**

BCE 5720 for further information

Analyser Based on Refractive Index

For cases where control of a process can be based on the detection of refractive index differences between a process stream and a desired sample, Phoenix have introduced a null type analyser designed for continuous operation. A recorder, based on a repeater principle, operates without batteries and standard cell, saving time otherwise required for zero control and recalibration. The analyser can be supplied with electric or pneumatic proportional controller. Various sensitivities to meet most applications are available combined with a range extension feature, allowing suppression up to ten times the standard range without initial zero shift or change of reference solution. The unit may be used for measuring and controlling impurities in process streams, concentration measurements or identification of compounds from fractionators, stills or chromatographic columns. It can also be supplied with a mass or volume collecting system which permits plotting of refractive index changes relative to the mass of the liquid sample passed. **Phoenix Precision Instrument Co., 3803-05 North 5th Street, Philadelphia, 40, Pennsylvania, U.S.A.**

BCE 5721 for further information

Chromel and Alumel Supplies

Genuine Hoskins Chromel and Alumel thermocouple wire is now available from stock in Great Britain. In addition, it will be bright finished instead of the existing dull oxidised finish.

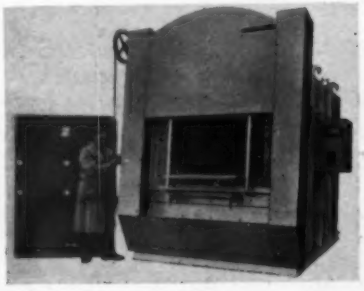
For many years it was thought impossible to maintain a bright finish on Chromel and Alumel wires during the long stabilising heat-treatments required to maintain consistent long-term accuracy. Because of this, it has become customary for the tenacious oxide film to be scraped away before making connections or welding a thermocouple junction. This will no longer be necessary with Hoskins alloys. It should lead to greater accuracy where millivoltmeter, rather than potentiometer, circuits are utilised, since the absence of an oxide film will give closer control over resistance values. **R. G. McLeod Tools Ltd., Lavina Grove, London, N.1.**

BCE 5722 for further information

HEAT EXCHANGE PLANT

New Furnace Range

Barlow-Whitney Ltd. announce their range of heavy-duty horizontal electric batch furnaces for all general heat-treatment processes. There are two basic models—series E-HDF 950 for operating temperatures to 950°C (maximum 1000°C) and series E-HDF 1100 for operating temperatures to 1100°C (maximum 1150°C). In the former type the heavy-gauge 80-20 nickel-chromium spiral heating elements are housed in specially moulded carriers and operate at normal mains voltage, whereas in the higher temperature models strip elements are employed fed from a step-down transformer at a reduced voltage.



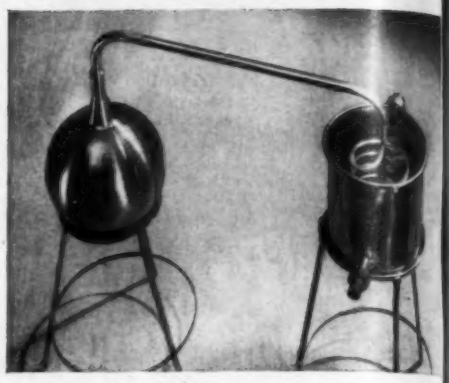
Both types are available in chamber sizes from 18 in. wide by 9 in. high to 48 in. wide by 36 in. high with optional front to back depths up to 96 in. Temperature is controlled automatically, and optional features include door heating, retractable loading platform, gas curtain and on the larger units zone control and power-operated door. **Barlow-Whitney Ltd., 2 Dorset Square, London, N.W.1.**

BCE 5723 for further information

DISTILLATION EQUIPMENT

A Pure Platinum Still

This unusual piece of chemical plant, required for distilling a highly corrosive fluid, is one of three destined for a Far Eastern government. It consists of a 5-in. diameter spherical distillation unit fabricated from 0.020 in. thick platinum connected by a platinum tube 11¼ in. long of 0.400 in. bore and 0.015 in. wall thickness, to a five-turn helical cooling coil constructed from platinum tubing of 0.200 in. bore and 0.012 in. wall thickness.



Platinum is, incidentally, the most corrosion-resistant of all the metals and alloys available to the designer of chemical plant. **Johnson, Matthey & Co. Ltd., Hatton Garden, London, E.C.1.**

BCE 5724 for further information

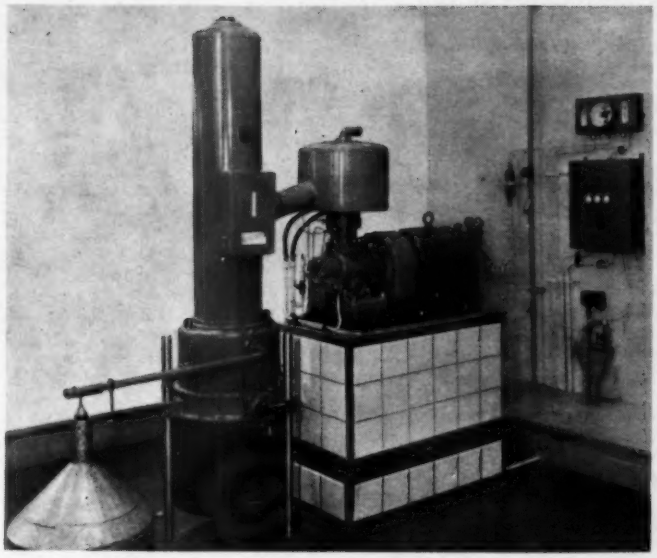
Molecular Distillation

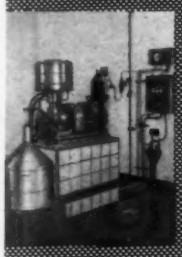
Edwards High Vacuum have forwarded us some preliminary details of a new range of molecular stills which they are just introducing to the market. The stills are 2 in., 4 in. and 12 in., the latter two being designed for continuous operation with feed rates up to 14 lb/hr for the 4-in. still and up to 200 lb/hr for the 12-in. still. These figures, however, are maximum throughput rates, the actual feed rates being dependent on the operation being performed and the material being processed. As a general indication of the operating range of these units, the substances which lend themselves to this process will have molecular weights ranging from 200 to 1250 (hydrocarbons) or up to 4000 in the case of silicones. Both the 4 in. and 12 in. have provision for the recirculation of the residue, should this be necessary. The 2-in. still is primarily a laboratory unit and is designed for batch operation, the feed flask having a capacity of 500 ml. All units are supplied complete with heaters, valves, measuring equipment and frames. **Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex.**

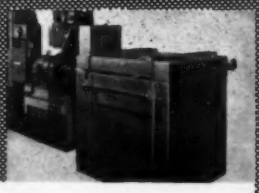
BCE 5725 for further information

Distillation Apparatus with Temperature Cut-out

For the routine testing of refinery products where the value of a single point on the distillation curve provides sufficient information for day-to-day volatility control, F. J. Hone have introduced a simple distillation apparatus. It is made under licence from The British Petroleum Co. Ltd. In operation, 10 millilitres of the sample is introduced into a flask, a thermocouple is inserted into the







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PHILIPS LIQUID NITROGEN INSTALLATION

- **Produces 4-5 litres (1 gallon) of 99.5 % pure liquid nitrogen per hour or more than 500 litres (110 gallons) per 6 working days;**
  power consumption at the motor shaft amounts to 6 kW.
- **Full output within 90 minutes from starting-up;**
  evaporation losses are reduced substantially with the new unit since liquid nitrogen is produced only when needed.
- **The air separation column has no moving parts;**
  The Philips Gas Liquefier is employed as nitrogen condenser.
- **Special devices ensure nitrogen purity and fool-proof operation;**
  this means: minimum attention and maintenance.
- **Moisture and carbon dioxide removed by freezing;**
  no chemicals, no reactivation required.

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for liquefaction of atmospheric air and other gases; production rate 5 litres of liquid air per hour.

380 litres cold box equipment
for storage, testing or cold treatment of materials from room temperature down to -160° C (-255° F); refrigerating capacity at -100° C: 1110 kcal/hr (4440 BTU/hr) and at -160° C: 640 kcal/hr (2560 BTU/hr) respectively.

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PLANT EQUIPMENT NEWS

neck of the flask and a receiver placed in position. The heater is then switched on, and when the selected temperature is reached an automatic cut-out switches off the heater. After allowing half a minute for draining, the volume of the distillate to the nearest 0.05 ml. is then noted. Residue in the flask is then removed by suction. The complete operation takes 10 min., of which less than 3 min. is operator's time. A booklet containing detailed instructions and wiring diagrams is issued with each unit. **F. J. Hone & Co. Ltd., 19 Eldon Park, London, S.E.25.**

BCE 5726 for further information

VALVES AND PIPEWORK

"Turbro" P.V.C. Valves

Turner & Brown are now producing P.V.C. valves in sizes ranging from ½ in. to 6 in. bore. They employ conventional metal bonnet assemblies (a frequent source of trouble in wholly plastic valves) incorporating neoprene, hypalon

or nitrile rubber diaphragms. The valve bodies can be supplied with either standard or non-standard flanges, complete with mild-steel backing rings. These valves are chemically inert up to 70°C, and are virtually unbreakable; a unique feature is the compression-type P.V.C. flange and loose backing ring which enables the valve to be set readily at any angle. Deliveries are rapid. **Turner & Brown Ltd., Davenport Works, Bolton.**

BCE 5727 for further information

Butterfly Valve for Reactor Use

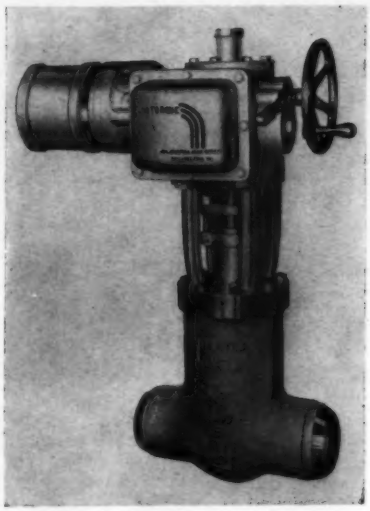
The 60-in.-bore motor-operated butterfly valve illustrated is being supplied by Blakeborough for main gas duct service on atomic power reactors. It is a stressed seal type and its design allows a relative expansion between the valve disc and

body, yet it permits a positive seal to be applied in the shut position. Ease of operation and tight seating are assured, the manufacturers state, under conditions of substantial pressures and thermal shock. **J. Blakeborough & Sons Ltd., Brighouse.**

BCE 5728 for further information

Valve Actuator and Control

The newly-formed company, Limitorque Valve Controls Ltd., are manufacturing in Britain and are marketing the Limitorque automatic valve actuating device for controlling and limiting the opening of valves of all types, sluice gates and bulkhead doors, etc. The design and specification will be those of the manufacturer's parent company in Philadelphia, which have been in use in the U.S.A. for over 30 years. The units can be fitted to a valve in any position, and they can be adapted for use with existing hand-operated equipment by replacing the valve yoke with a yoke adaptor. Almost any power source may be used, including electricity, air, hydraulic power and high-pressure gas. The makers state that the units are very suitable for use where emergencies may dictate rapid positive action. Should an obstruction be met whilst the valve is closing, a torque limit switch automatically disconnects the power source. The seating may be adjusted to compensate for normal valve wear or other changing service conditions. High-efficiency precision gearing is



used, the first reduction being by helical gear and pinion, and worm and wheel making up the second and final drive. The worm gear drives the valve nut assembly through two lugs to produce a "hammer-blow" effect which allows the motor and gears to obtain full speed before torque is applied to the valve stem. The purpose of this mechanism is to ensure that "sticky" valves will be freed. In the larger units the hammer-blow device is applied to the handwheel to avoid the valve becoming frozen in its seating, should there be a power failure. **Limitorque Valve Controls Ltd., Newbury, Berks.**

BCE 5729 for further information

New Publications

The British Plastics Federation have recently announced a new edition of their booklet on "Surface Coating Resin Index" (copies from **The British Plastic Federation, 47 Piccadilly, London, W.1,** and the **Surface Coating Synthetic Resin Manufacturers Association, 79 to 80 High Holborn, London, W.C.2**). This new version supersedes that published in 1955, and was prepared jointly by the two organisations. Its aims are to give under one cover the basic information on all the British-made surface coating synthetic resins at present available to the paint, printing ink and allied trades.

BCE 5730 for further information

Four new publications have been received by us from Hewittic. R192/1 deals with Cooled Cathode Rectifiers; R193 with Germanium and Silicon Rectifiers; R260 with Oil-immersed Rectifier Equipment; and R261 with Metal Rectifier Equipments. **Hackbridge & Hewittic Electric Co. Ltd., Walton-on-Thames, Surrey.**

BCE 5731 for further information

Bakelite have announced the publication of Advance Information Sheet E.32 which gives full details of three new low-cost epoxide resin hardeners now being marketed by the company. Bakelite say that the cost of epoxide resins has, up to now, tended to restrict their use. With the introduction of their new hardeners DQ.19124, DQ.19125 and DQ.19129, they state that this situation has been markedly altered and it is now possible to formulate epoxide resin/hardener mixes at appreciably lower costs. Copies of Sheet E.32, which gives typical characteristics of the systems and a number of suggested uses, are available direct from **Bakelite Ltd., 12 Grosvenor Gardens, London, S.W.1.**

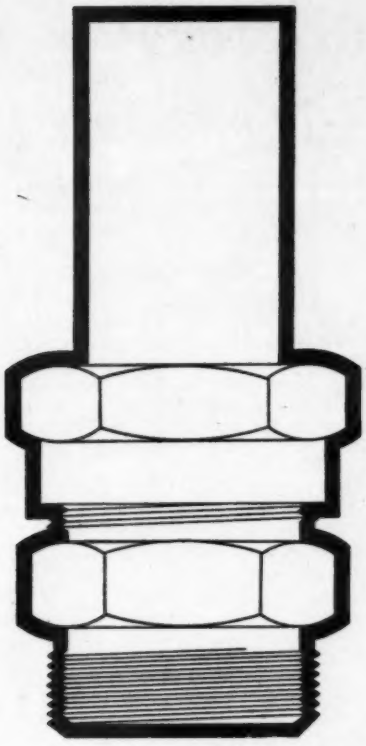
BCE 5732 for further information

Schrader's have announced their new price list for air control products for industry manufactured by the company. Copies from **A. Schrader's Son, 829 Tyburn Road, Erdington, Birmingham, 24.**

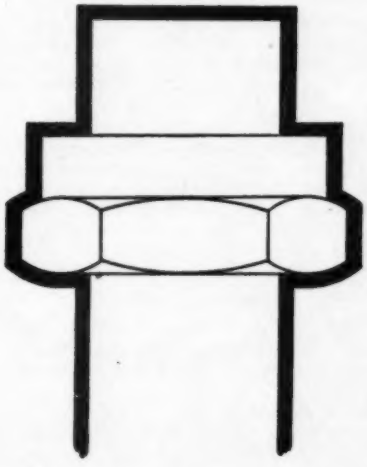
BCE 5733 for further information

A copy of Holmes' latest brochure on the Holmes-Western gas valves, which not only deals comprehensively with five main groups comprising the "55" range, but also has a section devoted to earlier types of Western valves, has reached us. Copies of this brochure are available on request from **W. C. Holmes & Co. Ltd., P.O. Box No. B.7, Turnbridge, Huddersfield.**

BCE 5734 for further information



the applications of Ermeto high pressure couplings are practically unlimited



ERMETO couplings are supplied in a wide range of standard fittings for all forms of high pressure pipeline systems. Non-standard fittings can also be made to suit individual requirements. Technical advice and fully illustrated catalogue will gladly be supplied on request.

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Month's News in Brief

B.N.F.'s New Laboratory

On May 13 Sir Alexander Fleck, chairman of I.C.I., opened the first laboratory block built by the British Non-Ferrous Metals Research Association since the war by unveiling a plaque engraved in titanium, symbolic of the newer non-ferrous metals. The new building has been made possible by the generous response of members to an appeal for special contributions to an extension fund and of the Department of Scientific and Industrial Research, who have treated these voluntary contributions as grant-earning. Among the more interesting research work of particular importance to chemical engineers is that being carried out in the Corrosion Section of the laboratories. Work on condenser tube corrosion has evolved a new range of alloys to meet the problems encountered with heat-exchanger tubes in power stations and oil refineries built on tidal estuaries where highly polluted waters have to be used for cooling. The new alloys are said to meet many of the corrosion problems met with under such conditions.

Lead, as is well known, has an outstanding resistance to corrosion, particularly towards sulphuric acid and sulphur-containing fumes. Lead, however, must be well supported, as it tends to creep even under its own weight. At the B.N.F. an investigation on lead-clad steel has progressed to the point where it is hoped to place the commercial production of the new product with an industrial concern. The B.N.F. have developed a method whereby the lead is rolled on to sheets of steel up to ¼ in. thick on large steel plates which can then be welded together without undue difficulty. The new product, when finally evolved, should offer tremendous advantages to chemical plant manufacturers.

A demonstration of an automatic fluorescent x-ray spectrometer by Solartron, which can automatically analyse 12 elements with a predetermined accuracy for each element and record the results on a paper tape, was given at the opening. This instrument should create a wide interest in the metals industry and has obvious advantages for quality control in metal foundries.

European Centre for A.C.M.s

For a number of years the Directors of the Associations of Chemical Manufacturers in Western Europe have found it useful to meet from time to time to examine together questions of common interest. In view of the number and scope of the problems facing the chemical industries of these countries at the present time, the Austrian, Belgian, British, Dutch, French, German, Italian, Swedish and Swiss Chemical Manufacturers' Associations have decided to improve their collaboration and contacts by setting up a Centre Europeen des Federations de l'Industrie Chimique (C.E.F.I.C.), the secretarial services of which are entrusted to the Swiss Association in Zürich. C.E.F.I.C. is a working agency of the Directors and will be responsible for organising their meetings and for the exchange of information. Contact with the Centre will be solely through the Directors of the member countries.

Contracts

By the terms of the agreement made between British Oil Equipment Credits Ltd. (subsidiary company of the Council of British Manufacturers of Petroleum Equipment) and Petroleos Mexicanos (PEMEX), petroleum equipment to the value of £3½ million will be purchased in Great Britain for the construction of a platforming unit for the Minatitlan Refinery in Mexico.

A £300,000 contract has been placed with Birwelco Ltd. and their subsidiary, Brown Fintube (Gt. Britain) Ltd., both of Aston, Birmingham, for the supply of six Petro-Chem Iso-Flow furnaces and tank heaters at the Rio Duque de Caxias refinery, Brazil, for Petroleo Brasileiro, S.A. Main contractor for the refinery is the Foster Wheeler Corp. in conjunction with Foster Wheeler Ltd., London, who are handling procurement in the sterling area.

Courtaulds Ltd. and the trade delegation of the U.S.S.R. in the United Kingdom announce that Prinex Ltd. (a subsidiary of Courtaulds Ltd.) and the Soviet importing trade organisation, V/O Techmashimport, Moscow, have concluded certain major contracts worth approximately £15 million. These cover the supply of complete plants and technical processes for the manufacture of viscose rayon tyre cord, acrylic staple fibre and cellulose acetate yarn.

The British Council for the Promotion of International Trade has announced that an order from Rumania for a paper and cellulose plant worth £5 million has been secured by Lyddon & Co., acting with Black Clawson.

News Briefs

British Titan Products Co. Ltd. have completed a major extension to their titanium pigment producing plant at Grimsby. Construction has taken two and a half years and has cost over £2 million. The new project, planned entirely by B.T.P. staff, brings the total output of the Grimsby plant to 70,000 tons a year. It is concerned mainly with the manufacture of the various Rutile grades of titanium pigments, supplementing the production of Anatase grades at the B.T.P. plant at Billingham-on-Tees.

Three miles of carbon steel tubing were used in each of the air blast coolers recently completed by Spiro-Gills Ltd. for the Kuwait Oil Co. Ltd. for installation in their first natural gas injection plant. Daily, 86,300,000 cu. ft. of natural gas will be cooled, at pressures of 1200 psig and 2600 psig respectively in the inter and after coolers. The gas will

Sir Alexander Fleck, chairman of Imperial Chemical Industries Ltd., unveiling a titanium plaque at the opening of the new laboratory block of the British Non-Ferrous Metals Research Association.

be cooled from 283°F to 140°F in the inter cooler, and from 296°F to 144°F in the after cooler.

In their Annual Review for 1958, the Solartron Electronic Group report that during the year to June, 1958, export orders were worth more than three times their orders for 1954 from all sources, whilst total value of orders received at £1.9 million represented a 52% increase over the previous year. This was achieved during a year in which major production facilities were re-located and with only a 38% increase in personnel. The current figures of orders for the preceding 12 months approximated £2¼ million.

Since 1948 the pharmaceutical industry's output and exports have more than doubled, with an increase in the labour force of under 10%. In 1948 the industry, employing 48,600, had a turnover of £73 million, of which £15.8 million was exported; the provisional figures for 1957 show that the industry, employing 52,400, had a turnover of £150.4 million, of which £39.6 million was exported. These figures are given in the recently published Annual Report and Year Book 1958/59 of the Association of British Pharmaceutical Industry.

The British Engineers' Association is planning a Trans-Canada mobile exhibition of engineering equipment which will metaphorically take British products to the door-steps of Canadian purchasers. The plan provides for a train of up to 60 specially-designed show cars to carry a comprehensive exhibition of U.K. engineering products from coast to coast across Canada during May and June of 1960. Starting at Vancouver, the journey will take approximately two months and is expected to cost about £½ million. Calgary, Edmonton, Winnipeg, Toronto, Montreal, Ottawa and Halifax are among centres likely to be visited.

The National Coal Board is to step up its programme of methane gas extraction from deep mines. The present 62 drainage plants in the U.K. are to be increased by about 25 in the next three years. The new programme is aimed at raising the amount extracted to over 200 million cu. ft, and the amount used to over 150 million.

Kelvin House, built at a cost of

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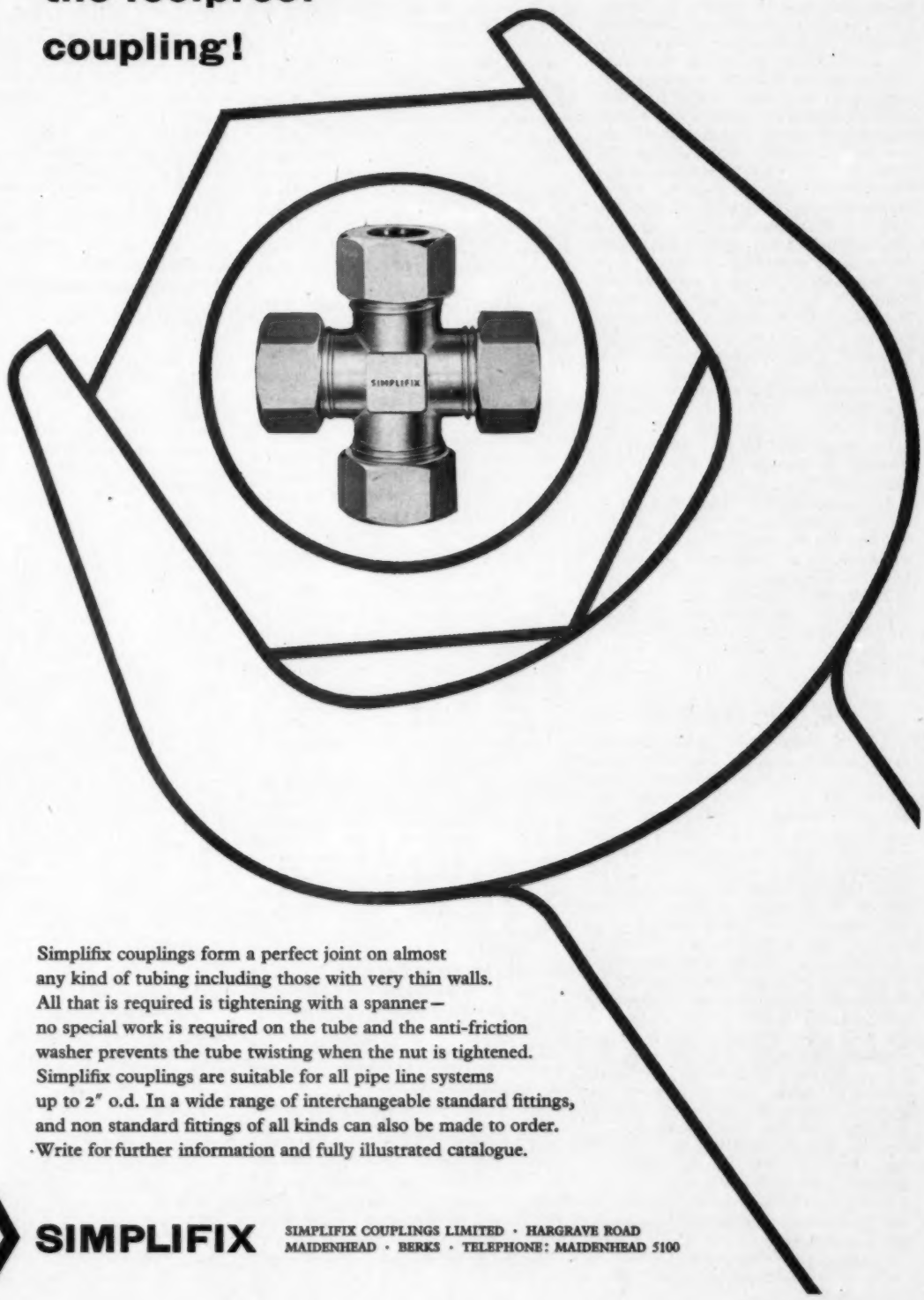
So surely SIMPLIFIX the foolproof coupling!



Simplifix couplings form a perfect joint on almost any kind of tubing including those with very thin walls. All that is required is tightening with a spanner— no special work is required on the tube and the anti-friction washer prevents the tube twisting when the nut is tightened. Simplifix couplings are suitable for all pipe line systems up to 2″ o.d. In a wide range of interchangeable standard fittings, and non standard fittings of all kinds can also be made to order. Write for further information and fully illustrated catalogue.

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£250,000 for Kelvin & Hughes Ltd. at Wembley Park, was officially opened by Sir David Eccles, K.C.V.O., M.P., President of the Board of Trade, at the beginning of May.

The Council for Scientific and Industrial Research announces that in future the Mechanical Engineering Research Laboratory at East Kilbride, near Glasgow, will be known as the National Engineering Laboratory. The change of name is to emphasise the national character of the laboratory and does not imply any change in the field covered by the Laboratory, which will continue to be concerned with problems of mechanical engineering. To look after the programme of the laboratory, the Council has decided to set up a Steering Committee which will be under the chairmanship of Vice-Admiral Sir Frank Mason, who is a member of the Research Council and chairman of the outgoing Mechanical Engineering Research Board and a director of Metal Industries Ltd. Other members of the Committee are: Prof. O. A. Saunders, Professor of Mechanical Engineering at the Imperial College of Science and Technology, University of London; Norman Elce, director and chief mechanical engineer of Metropolitan-Vickers Electrical Co. Ltd.; Dr. D. G. Sopwith, Director of the Mechanical Engineering Research Laboratory; and Dr. C. M. Cawley, Director of Stations and Grants Divisions, D.S.I.R.

The recent Henry Wiggin & Co. Ltd. exhibition held at Park Lane House, London, on the diverse uses for high-nickel alloys in numerous industries is to tour the provinces. It is to be held in Birmingham (Imperial Hotel) from October 5-9 and Manchester (Midland Hotel) October 12-16. Lectures and film shows form an integral part of the exhibition.

People in the News

At the thirty-ninth annual general meeting of the British Chemical Plant Manufacturers Association held recently in London, the retiring chairman, **Mr. H. W. Fender**, vice-chairman and managing director of Prodorite Ltd., was re-elected for a further year. The following were elected to the Council: **Mr. P. D. Doulton**, Matthew Hall & Co. Ltd.; **Mr. E. S. Franklin**, Torrance & Sons Ltd.; **Mr. N. C. Fraser**, W. J. Fraser & Co. Ltd.; **Dr. R. Lessing**, The Hydronyl Syndicate Ltd.; **Mr. R. C. Odams**, Constructors John Brown Ltd.; **Mr. B. N. Reavell**, Kestner Evaporator & Engineering Co. Ltd.; **Mr. R. W. Rutherford**, The Power-Gas Corporation Ltd.; **Mr. P. W. Seligman**, The A.P.V. Co. Ltd.; and **Mr. R. F. Stewart**, Dorr-Oliver Co. Ltd. After the annual general meeting the Council elected the following officers: vice-chairmen: **Mr. N. C. Fraser**; **Dr. R. Lessing**; **Mr. P. W. Seligman**; and as hon. treasurer **Mr. M. H. Wyndham**, Bennett, Sons & Shears Ltd.

At its annual meeting the Council of the Association of British Pharmaceutical Industry elected **Mr. E. D. Carey**, managing director of Imperial Chemical Industries Ltd. (Pharmaceuticals Division), president for the year 1959/60. **Mr. H. W. Palmer**, managing director of Glaxo Laboratories Ltd., was elected vice-president. **Mr. G. T. Morson** was re-elected Honorary Treasurer.

At the recent annual general meeting of the British Rubber and Resin Adhesive Manufacturers' Association **Mr. D. E. Cameron**, of B.B. Chemical Co. Ltd., was re-elected chairman, and **Mr. N. G. Bassett Smith**, of Dunlop Rubber Co. Ltd., as vice-chairman.

Mr. D. M. Boyd, a director of Fisons Ltd., has been elected chairman of the Association of Chemical and Allied Employers. He succeeds **Sir Laurence Merriam**, who retires after a two-year term of office. Mr. Boyd has relinquished his duties as production director of the Fertilizer Division of Fisons in order to devote himself fully to the new appointment. He will remain a member of the Fertilizer Division Board and continue as a director on the main board of Fisons.

Mr. D. G. Gillies, sales manager of the Process Engineering Division of Alfa-Laval Co. Ltd., has been appointed to the board of directors.

Mr. D. N. Gifford, commercial manager, has been appointed a director of Birlec-Efco (Melting) Ltd., Westgate, Aldridge, Staffordshire.

Head Wrightson & Co. Ltd. announce that the **Earl of Halsbury** has joined the board of Head Wrightson Processes Ltd.

Mr. W. Hackett, Jnr., and **Mr. R. D. Young** have been appointed assistant managing directors of Tube Investments Ltd.

Dr. W. Steven has been transferred to the Development and Research Division of The International Nickel Company Inc., New York, as director of research. He has also been elected an assistant vice-president of that company. Previously he was superintendent of the Development and Research Department Laboratory of The Mond Nickel Co. Ltd. in Birmingham.

Dr. G. L. J. Bailey has succeeded Dr. Steven as superintendent of the Development and Research Department Laboratory in Birmingham. It has also been announced that **Dr. W. Betteridge** has been appointed superintendent of the Platinum Metals Research Laboratory of the Development and Research Department.

Sharples Centrifuges Ltd. announce the appointment of **Mr. E. C. C. Harvey** as senior project engineer responsible for the company's activities in South-east England.

J. Banks, who is connected with BRITISH CHEMICAL ENGINEERING, arrived in London on May 26.

Mr. W. K. Moore has been appointed manager of the newly-formed Gas Cleaning Division of Steels Engineering Installations Ltd., Sunderland. This division has been formed to manufacture SPA dust collecting equipment, for which Steels hold an exclusive licence in the U.K.

Mr. R. S. Hewitt has joined the board of Elliott Bros. (London) Ltd. Mr. Hewitt started his career with Elliott Bros. in 1928 and is deputy controller of Elliott-Automation.

Mr. C. Bontemps has been appointed general sales manager of Charles Lennig & Co. (Great Britain) Ltd. Mr. Bontemps comes to Lennig from the parent company, Rohm & Haas of Philadephia.

Obituaries

We regret to announce the death of **Mr. H. Curtis** on Wednesday, May 20, 1959, at the early age of 39. Mr. Curtis was a friend of this journal who had helped us both with suggestions and introductions. He was an Honours graduate of Manchester College of Technology in chemical engineering and was elected an Associate Member of the Institution of Chemical Engineers in 1949. Mr. Curtis was also elected an Associate of the Royal Institute of Chemistry in 1943.

After working during the war with chemical firms he went to Sondes Place Research Institute in 1948, where he took part in various investigations. From there he went to Leda Chemicals Ltd. in 1950 as chemical engineer at a time when the firm was starting to manufacture fine chemicals. During his service with this firm, Mr. Curtis designed and constructed plant for the manufacture of quaternary ammonium compounds, cyanamide monomer and a range of other fine chemicals, notably rubber chemicals such as alkyl dithiocarbamates.

For the year 1953-4 he went out to Israel and worked on process development with Israel Mining Industries Ltd. On returning he was elected a director of Leda Chemicals and its associated companies, Cunningham Smith Co. Ltd. and Lea Valley Chemicals Ltd., becoming responsible for production and chemical engineering in these companies. Early in 1958 he was sent to the U.S.A. on behalf of F. W. Berk & Co. Ltd., in order to examine possible processes for development in Britain.

Mr. Curtis had also served on the London and Home Counties Area Training Committee set up under the scheme for training qualified chemical operators by the Association of Chemical and Allied Employers and the trade unions.

He had a most agreeable personality and was well liked among his colleagues of all grades. Many tributes to him have been expressed among both technical and production staffs in the establishment where he worked.

We regret to announce the death in New York on Friday, May 8, of **Mr. Chester B. Morrison**, late chairman and managing director of York Shipley Ltd.

Mr. Morrison was appointed managing director of the company in June, 1940, and retired as chairman in July, 1958.

Q.V.F. Ltd., Stoke-on-Trent, announce with regret the death of **Herr Heinz Meinecke**, manager of Q.V.F. Glastechnik, their subsidiary company in Wiesbaden, Germany. Herr Meinecke had been manager of Q.V.F. Glastechnik since its inception in 1956.